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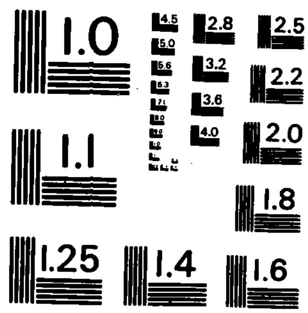
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NAVAL POSTGRADUATE SCHOOL
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THESIS

MATERIAL REQUIREMENTS PLANNING AND LOGISTIC SUPPORT FOR A FIELD SERVICE ORGANIZATION: A "REAL WORLD" EXAMPLE

by

Gary W. Strawn

June 1982

Thesis Advisors: J. W. Creighton
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The report includes a series of memorandums to the company recommending pragmatic solutions to the problems. The company has implemented the recommendations.

Material Requirements Planning and Logistic Support for a Field Service Organization: A "Real World" Example

by

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Submitted in partial fulfillment of the
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ABSTRACT

In an effort to better understand the problems and advantages of utilizing commercial contract service support for complex military electronics systems, the author seeks to analyze a large electronic equipment manufacturer's inventory management system as it is used to support a field service division. A cost analysis of plausible shipping and storage strategies is performed. The complexities of adapting a material requirements planning system to provide improved inventory management for the unscheduled demands of a service organization, are discussed.

The report includes a series of memorandums to the company recommending pragmatic solutions to the problems. The company has implemented the recommendations.

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I. INTRODUCTION

A. BACKGROUND

As a Naval Aeronautical Maintenance Duty Officer, my assignment prior to the Postgraduate School, was as a Fleet aviation maintenance facilities manager. As such, I became involved in negotiating for contractor support of Aircraft Support Equipment. I am convinced that the future will see an increasing role in contractor support for many of the Navy's sophisticated and highly specialized automated test systems.

After dealing with this problem from the Navy side, I became increasingly aware of my own lack of knowledge of the contractor's methodology and capabilities to provide such support. My Navy counterparts and I tend to look at contractors as operating in a mythologically ideal logistics environment, that is incapable of responding to the intricate problems of fleet logistical support.

My primary intent is to learn how a major industrial firm handles its logistics problems, specifically those relating to the field service area. If, during that process I can become involved in analyzing and solving some "real world" problems then all the better. A major goal is to ensure that my efforts will compensate the Company for investing their time and energy in me. The final result will be that the educational process is served.

B. THE COMPANY

Through a series of uncoordinated and unpredictable events, I came into contact with the managers of a large company located on the San Fancisco Penninsula. For reasons

of confidentiality, I shall call it "Kelly Incorporated", or more simply, "the Company". Kelly Incorporated is a Fortune 500 electronics manufacturing and high technology development firm. The Company is divided into groups, most of which do a great deal of Government contract buisiness including follow-on service support. In order to avoid any semblance of conflict of interest or personal bias, I selected a Group which produces highly sophisticated radiation machinery used primarily in medical applications. A variant is also being produced for heavy industrial applications. Some of these are in use in Navy shipyards, but it remains primarily a public sector business.

Approximately 874 machines have been produced and sold. There is a Field Service Division which currently employs seventy three field service personnel and provides maintenance and service support on a contract basis throughout the world. The Manufacturing Division is tasked with providing parts support to the field service organization, and sells parts for independently maintained machines both within the United States and overseas.

At the begining of the project, November 1981, most of the approximately 4800 line items of inventory were carried at the plant site in Palo Alto. Two smaller inventories were carried at the regional service centers in Atlanta and Chicago. Previously, approximately seven percent of the total inventory was spread out among other disbursed locations such as Los Angeles, Dallas and Washington, D.C., but these sites have been phased out. The inventory data for these sites was ignored as it was felt to be obsolete by the Inventory Manager.

Division management is becoming increasingly aware of customer dissatisfaction and lost service contracts caused by delays in the parts support system. The production line is being cannibalized to fill emergency field service

requirements, which can not be met by service support or manufacturing inventories. The Division Manager has directed that service support stock be increased to cover four months average demand. This was originally directed for parts which are no longer utilized by the Manufacturing Division. Parts for equipment currently in production were to be stocked at a two month demand level. To avoid delays and mix ups in determining parts applications, the policy was simplified to four months stock for all items. The stock is being divided between each of the three regional stockrooms, in accordance with their relative average demands.

The machines involved are costly, some approaching one million dollars each. Failures, particularly those in medical applications are extremely critical, and result in highly emotional and expensive delays. The Company is very concerned with providing rapid and reliable response to emergency service requests. It is considered important to ensure customer satisfaction with the existing service contracts, in order to retain them as potential customers for new and more sophisticated product lines.

C. OBJECTIVES

The researcher in this study was asked to provide an analysis of current and proposed service support procedures. The areas of analysis will be as follows:

(1) Location and relative size of the inventory points.

(2) Alternative methods for shipping required parts to the field.

(3) Inventory control procedures.

(4) Methods for projecting usage requirements.

(5) Integration of service requirments into the material planning functions of the Manufacturing Division.

A comparison of the relative costs and effectiveness of any feasible alternatives will be provided. Recommended courses of action will be delineated where warranted.

D. FORMAT

The project proceeded in three stages or sequential studies:

(1) Analysis of various inventory and shipping techniques utilized in support of Field Service operations.

(2) Material Planning for Service Support

(3) Implementation of Material Requirements Planning

Each stage culminated in a memorandum to the Division manager. The are presented in Appendixes A, B and C. [1]

A description of the methodology used in each of the studies is included as Chapter II. Chapter III provides a summary of the findings. Chapter IV contains a description of the process of implementing the recommended system modifications. Chapter V consists of some conclusions and comments on application to Defense contracting policies.

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[1]The memorandums have been edited to improve their compatability with the thesis format and to protect the Company's confidentiality. Some corrections have been made to the narative portions. However, the content remains essentially the same as it was presented to the Company.

II. METHODOLOGY

A. ANALYSIS OF INVENTORY LOCATION STRATEGIES

In response to the invitation to look into the Company's service support procedures, a few days were spent observing the operation. The most intuitively obvious area for possible improvement appeared to be in evaluting the heavy reliance on air frieght express forwarders to meet high priority demands. Nearly all requests received during the initial observation period, resulted in a relatively expensive express shipment to the service location. The frequency of cases where the cost of the shipment exceeded the dollar value of the items shipped seemed excessive. It was determined that a comparative analysis of the various options for stocking and shipping the required parts, should be undertaken.

Appendix A is a memorandum to the Manufacturing Manager analyzing the various options for disbursement of the Service Support inventories. The analysis involves varying the quantities and location of spare parts inventories and/or the modes, distances and frequencies of express shipments.

1. Alternatives

The options were limited to those which were realistically within the parameters set by Company policy and existing resources. Customer satisfaction is the primary concern of management. Therefore, parts required for repair of inoperative machines are required to be on site within twenty four hours. Alternatives which did not ensure twenty four hour delivery with at least ninety five percent probability were rejected as unacceptable.

Alt 0: Most parts carried in Palo Alto, with some items carried in Atlanta and Chicago (this system was in effect at the time of the sample).

Alt 1: Four months projected demand stocked at each regional site (Palo Alto, Chicago, Atlanta).

Alt 2: Entire four months projected demand stocked at Palo Alto.

Alt 3: One year projected demand stocked at each regional site.

Alt 4: A combination of the other alternatives based on a hypothetical "ABC" breakdown of the inventory.

The possibility of placing inventory at other than the three established regional stock points was discussed with management. It was rejected because of undesirable warehousing costs and additional inventory management requirements.

2. Analysis of Shipping Costs

Although Company policy dictates the use of air freight express only for top priority shipments, a sample of all of the shipments made during a selected five week period revealed that ninety nine percent were made via air freight express companies. Because of the minimum weight requirements imposed by the lower cost "common carriers", even routine stock replenishments were sent via air freight.

Average costs were computed for shipments from the factory to all points in the continental United States. These were compared with projected costs for the same mode of shipment from the appropriate regional stock points.

3. Analysis of Inventory Costs

The analysis of inventory costs included three basic categories: holding costs, ordering or set up costs, and stockout costs. The major component of holding costs is

the opportunity cost of capital. [2] Due to the high interest rates, the before tax return on investment was set at thirty percent. Therefore, the total holding cost was set at thirty six percent of the average value of inventory.

Stockout cost were not a factor in this analysis, since any alternative which did not provide the requisite ninety five percent fixed effectiveness were rejected outright.

B. EVALUATION OF THE INVENTORY CONTROL PROCESSES

Upon completion of the initial study, a meeting was held by the Manufacturing Division Manager, with the author, the Material Manager and his Project Manager. The results of the study and possibilities for pursuing a more cost effective approach to materials planning for service support were discussed. The material managers were receptive to the concept of an "ABC" breakdown of the inventory stocking criteria, but expressed a serious concern about the divisions ability to accurately develop the type of data necessary for such a complex inventory system.

Problems encountered by the service organization in predicting usage requirements were discussed. The diversity of product mixes and operating parameters faced by the various service areas was also reviewed. In addition, the continuing difficulty encountered in providing four month's average demand in inventory at the three regional sites, was considered. Those present at the meeting came to the unanimous conclusion that, an analysis of the existing procedures for determining inventory requirements was the next logical step.

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[2] Company management refers to this cost in terms of the required Return on Investment.

A follow-on study was instigated to investigate the posibilities of adapting or modifying the existing inventory control system, to the highly volatile and unpredictable demands of service support.

The study proceeded in three steps. First there was an evaluation of the current process for determining allocations to the regional inventory points. Secondly, it would be necessary to evaluate the capabilities and limitations of the Company's computerized inventory control system. A third portion of the study involved researching the current professional literature for comparison information and any applicable theories for adapting a manufacturing inventory control system to service support. [3]

C. PROVIDING VALID STATISTICAL FORECASTS

If the material requirements planning process was to be utilized, a reasonable statistical forecast had to be provided. The material planners expressed doubt as to the accuracy of the statistical forecast in the part history file of the inventory control system. The Service Manager expressed his belief that the usage data being submitted to the system was now accurate. However, it was stated that inaccurate statistical usage submission may have been the cause of past failures.

The question then centered on whether it would be better to utilize the existing statistical forecast, modify the formula or utilize a set value obtained from the other records.

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[3] A summary of the findings of this research was presented to the the Company in the of 3 March 1982, shown in Appendix B. A full report is included in Chapter III of this thesis.

The author offered to statistically analyze the statistical forecasts in the part history file, and the average usage figures utilized by the Inventory Manager, as predictors of future demand. A sample of 100 part numbers was randomly selected from 2800 parts which showed usage in the test period. Regression analysis was performed on the IBM 3033 computer at the Naval Postgraduate School, utilizing the IDA software package [Ref. 1]. The results are shown in Appendix D.

The regression analysis was followed by an evaluation of the statistical forecast algorithm as shown in Appendix E. The effects of variations in the exponential smoothing factor were discussed in the Memorandum of 20 April, 1982 (Appendix C).

D. IMPLEMENTATION

The next stage was delayed slightly due to a change in material managers, but the new manager was extremely interested in pursuing this matter. Another series of meetings of all concerned personnel was held to discuss the problem. It was agreed that a strong effort should be made to utilize the Company's material requirements planning system to relieve the inventory managers of the current laborious process. It was hoped that this would also improve the speed and accuracy of the inventory ordering process.

A task force to implement the recommended inventory planning procedures was established. It was headed by the Material Manager, with the Service Support Manager, the Material Planning Supervisor, the Data Control Supervisor, a Management Information Services representative and the author as members.

Reprogramming of the modules was to be avoided if possible, due to expense, delays, and potential interference with other system users. The Service Support Section of the

Manufacturing Division of the Medical Group, is such a small part of the Company, that changing the the inventory control programs beyond the designed tailoring options was unrealistic. At best it would be a time consuming and politically costly process. The desired result of this project was to optimize the utilization of existing programs, with the possible addition of a simple data base access program to review and update usage forecasts.

The Company offered the assistance of their Management Information Systems designers and programming personnel. The "Informatics Mark IV", data base managment system and the "Statistical Analysis System: SAS" were available for access into the extensive inventory control data base and extraction of appropriate usage breakdown listings.

The various implementation options are discussed in the Memorandum of 20 April 1982 (Appendix C). Recommendations for implementing the material requirements planning system for service support are made. The results are summarized in Chapter IV.

III. FINDINGS

A. RELATIVE COSTS OF INVENTORY LOCATION STRATEGIES

One finding of the shipping cost comparisons was that there is no significant cost savings in reducing the distance of a shipment, assuming the same mode of shipment is used. A comparison of rate tables for the three primary air freight companies showed that only ten percent of the total cost of any given shipment is determined by the distance to be covered. The relative size and remoteness of the destination, and consolidation of items into the smallest possible number of shipments/pick-ups can cause shipping cost to more than double or cut them in half, for any given distance [Ref. 2, 3 and 4].

The significantly lower intra regional shipping costs were attributed to the utilization of low cost carriers and direct pickups by service personnel.

1. Comparison of Alternatives

Table I provides a quick comparison of the quantifiable costs of the alternatives considered.

TABLE I

Total Annualized Costs of the Alternatives

Alt 0 (current mix)	$1,007,783
Alt 1 (4 month's stock at each region)	$ 527,926
Alt 2 (4 month's stock at Palo Alto)	$ 580,531
Alt 3 (1 year's stock at each region)	$1,302,388
Alt 4 (ABC breakdown)	$ 568,049

Alternative One appeared to offer the lowest quantifiable cost. However, when confidence intervals were computed based on the sample size at a ninety five percent confidence level the allowable variance was in the computed costs was $53,000. Therefore, neither alternatives One, Two or Four could be considered to offer a cost advantage.

Effectiveness then became the determining factor between the remaining alternatives. Alternative Three has the potential of improving effectivness by some unknown factor, but this must be weighed against additional cost. Alternative Four was a hypothetical proposal which offered the same potential for improved effectivness with the lower cost and advantages offered by Alternative One. Only Alternative Zero can be rejected based on cost and it had already been rejected by Company management for being ineffective.

It was recommended that Alternative Four be investigated further as the most promising alternative. Meanwhile, they should continue with the implementation of Alternative One.

B. EVALUATION OF THE INVENTORY CONTROL PROCESSES

1. The Current Service Support Procedure

The current process for determining stock allocations to the regional inventory points, is a complicated, time consuming manipulation of the the Company's computerized inventory control system. The results are questionable.

The following problem areas were identified:

a. Fabricated "Bills of Material"

The inventory manager has applied a great deal of time, energy and ingenuity in creating a "bill of material" for each inventory site. These "bills of

material", were actually an ingenious adaptation of a report designed to be used as a bill of material for an assembly in the manufacturing planning process.

b. Inacuracies in the Usage Data

Currently, a four month average demand for each part number in a regional inventory is computed from a report which was designed for tax purposes. The report reverts back to zero at the begining of the new fiscal year. Therefore, realistic averages can only be computed the last few months of the year.

c. Inefficient Utilization of the Inventory Control System

The reports being utilized are inefficient adaptations of the designed system. They waste computer time, and exceed the designated file size. Furthermore, the statistical forecasting features and lead time calculations are not being utilized.

d. Lead Time Computations

The inventory manager has access to three differing lists of component lead time. He attemps to compute lead times for required assemblies by manually combining data from these reports.

e. Cumbersome Manual Operations

The current system requires far too much manual input and variation of the mechanized reports. It is so complex and non standard that the managers are fearful of loosing the creator of the system, for even a short period of time. Although the required data is in the data base, the current menu of reports do not provide direct access to it.

2. The Company's Material Requirements Planning System

The Company's sophisticated computerized inventory control system includes material requirements planning and material control system modules, which have been highly successful in supporting the manufacturing operation. However, the inventory managers in the service support section have found the system to be unsatisfactory in computing inventory requirements to meet the unscheduled needs of the service organization.

The system is designed to compare the various costs associated with inventory including such factors as lead time, decoupling time and desired safety stock. It then computes the most economical quantity and schedules the ordering of parts to meet projected demands. [Ref. 5: sec.204]

The material requirements planning module receives projected demand for major assemblies from manufacturing master schedules, sales forecasts and memorandum inputs. The system explodes a bill of material for each major assembly and totals scheduled requirements by part number. A Statistical Forecast for unscheduled demands such as service support may be added to scheduled demand for each part.

The date of the assembly requirement is set back by the cumulative lead times and decoupling time for each higher level in the assembly's bill of material explosion process. The various requirements for a given part are grouped together for economic ordering. Required quantities are increased by a replacement issue factor (yield factor) and a safety stock allowance. [Ref. 5: sec.204]

a. Yield Factor

The yield factor is designed to allow for losses during the manufacturing or procurement process. It is calculated by dividing the sum of the quantity actually received in a selected period of time (one to nine months) by the number ordered. This factor is recorded in the part history file.

b. Safety Factor

A safety stock allowance is developed based on the assumption that statistical variations in demand will follow a Poisson approximation to an exponential distribution. For any percentage of stock-outs deemed acceptable by management, a safety stock multiplier is derived from Poisson probability distribution tables. These multipliers are applied against the square root of the product of the average daily statistical usage, lead time in M-days, and the average units on one "statistical" requisition. [Ref. 5: sec.204]

The safety stock multiplier has been set in the material control system at 1.65 for parts with a unit cost greater than one dollar, and 2.33 for those less than one dollar.

The total of all requirements, schedules, forecasts, safety factors etc., are compared with the on hand inventory and scheduled gains. The date of the first unfilled order becomes the required delivery date.

c. Economic Order Quantity

The next procedure is designed to determine if it is economical to increase the size of the order by including successive requirements. Savings in procurement costs are compared with increased costs of holding the parts in inventory. Computations are then made to determine how

many "part days" of holding costs it takes to equal the cost of an additional set up or order. This is expressed as a derivative of the standard economic order quantity formula:

$$Q = \sqrt{2DS/HP}$$

The following formula creates the term "A" as a comparative value expressed in "part days".

$$A = S/hP$$

The terms involved are:

S = set up or ordering cost

H = holding cost expresed as a percentage of unit price (includes storage space, handling, taxes, insurance, obsolescence, deterioration, and cost of capital)

P = unit price

T = interval between requirements (in manufacturing days)

R = quantity of the next requirement

D = annual demand

h = daily holding costs

The "part days" for each successive requirement are computed as R times T. When R times T is greater than A, a new order is scheduled. If R times T is equal to or less than A, the quantity of the original order is increased to cover the successive requirements. [Ref. 5: sec.204]

The required delivery date determined by the above process is further set back by the cumulative lead time and decoupling time for each lower level in the assembly's bill of material explosion process. This yields the required time phased order point quantity.

d. Statistical Demand Forecasting

The Company's material requirements planning process allows for additional demand, that not reflected in the production forecast, to be computed from historical data. All parts issued to such requirements as service

support should be documented with a transacton code identifying "Statistical Usage". The only acceptable method of planning for such requirements is through historically based projections. Utilizing other forecasts such as soliciting predicted demands from service personnel in the field have been rejected by management, as being to subjective and variable.

The material control module calculates a daily usage figure, called a Statistical Forecast, by using an exponential smoothing / weighting factor technique. The Statistical Forecast is a perpetual figure stored in the Part History File for each item. Each month the old value is updated in accordance with the formulae described in Appendix B. With the Company designated exponential smoothing factor of 0.2, the demand during the most recent month is weighted at twenty percent against eighty percent for the old figure computed from an unlimited number of previous months. The results are further modified by a weight factor or trend predictor shown as "W" and "T" in Appendix E. The results are a smoothed demand curve which becomes increasingly flat and less responsive to change with successively smaller exponential smoothing factor.

The stochastic process assumes that the demand is relatively constant. Therefore, it is accurate only for short periods. Since it is repeated at monthly intervals, the effects of variations are minimized. [Ref. 5: sec.207]

Whether or not such weighting and smoothing modifications to the statistical usage data is desirable in this case has been a point of contention among the managers. The resulting figures have been considered unacceptable by the material managers in the past, for several possible reasons: improper coding of statistical issues, anomalies in the regional stock issue procedures, or variations in demand beyond that approximated by the calculations.

3. Comparison with the "State of the Art"

Although, in this day of rapidly changing data processing and management information technology, a twelve year old system might be presumed obsolete, a search of the latest applicable literature shows otherwise. The design parameters and theory behind the Company's inventory control programs, which were written in 1969, are very closely aligned with those presented in currently used texts and professional journals on the subject. The economic order quantity model remains basically unchanged since its development in the late 1930's [Ref. 6: p.32]. The material requirements planning process grew out of time phased demand techniques in the early 1960,s as computer technology allowed more complex computations and larger, more accurate data bases [Ref. 7: p.20].

When all of the options built into the Company's material control and material requirements planning modules are combined, the user is provided with any of the classical inventory planning system variations such as: fixed lot size with perpetual or periodic inventory cycles, fixed reorder interval or fixed reorder point [Ref. 8: p.164]. If desired, a dynamic programming algorithm which optimizes lot size for any given set of holding and set up cost parameters, is available as an option within the Company material control system. It is based on the Wagner-Whitten Algorithm [Ref. 9]. It is also possible to fix order quantities, or compute them with either set up or holding costs set at zero, without modifying the existing program. The Statistical Stabilizing Options provide the ability to vary the effective periodicity of the economic order quantity calculations, and the Audit Cycle Option provides a traditional "ABC" breakdown for inventory monitoring efforts.

Whybark and Williams [Ref. 10], discuss material requirements planning under uncertain demand forecasting. They suggest that there are significant differences between buffering inventory with safety stock or with safety lead time, depending on the source of the uncertainty: timing or quantity. Their experimentation, deals with high variability in manufacturing schedules. In such cases, lead time retains great importance. The demands, regardless of their variability are real requirements. In the case of statistical forecasts for service support inventories, the "demands" placed are only guesses at future requirements. The fact that the accuracy of the forecasts decrease with lead time tends to negate the desirability of long lead times. The point to be made here is that the Company's material requirements planning module contains options to cover both cases.

There is a great variety in existing inventory systems. They vary in size and in the stochastic processes inherent in the systems. These differences have a great deal to do with the operating doctrine being served.

There has been some interesting, research on the effects of wide variations in demand, beyond the Poisson approximation to an exponential distribution [Ref. 11 and 12]. In fact, studies have indicated that the rate of failure of mechanical devises, similar to the majority of failing components in the machines of this study, most often follows a more complex Weibull Distibution [Ref. 13: 5]. Although much research has been done in developing abstract mathematical properties of inventory models, an opposing faction is concentrating on practical application [Ref. 6: p.4].

In his "Focus Forecasting" theory, B. T. Smith proposes the use of simple computer produced models of current usage trends vice complex statistical forecasts and

exponential smoothing techniques. His contention is that the planning process must be simple and easily understood before it will gain wide spread acceptance. Smith contends that the use of exponential smoothing, which is simply a mathmatical approximation of a moving average, is no longer necessary. The speed and efficiancy of modern computers will allow more lengthy processes which are more in line with common business practices. For example, a manager may believe that demand for his inventory usually follows the trends of the last three months. Others might be best modeled after seasonal usage of the previous year. The speed of modern computers allows these and other forecasting strategies to be tested for each item, through a process of simulation. The method which yields the closest approximation during simulation of the past three months, is then selected for use in the next month. [Ref. 14: p.2]

Hall and Vollman analyzed successful and unsuccessful material requirements planning systems and establish the pivotal factor to be managerial involvement. Market factors, capital intensity and corporate strategy all contribute to the success or failure of a material requirements planning system. [Ref. 15]

Many other articles in recent professional journals deal with problems of implementation rather than technical problems with the system itself [Ref. 16]. They address problems very similar to the one in this case. What can be done to make a sophisticated material requirements planning system responsive to specific situations? Even more fundamentally: how does one cause an operable system to be utilized?

4. Status

At the end of the first four month period under the existing system, only 50.7 percent of the computed stock

requirements were actually shipped. Reasons cited for this failure are lack of manpower to process the shipments and long lead times required for procurement or manufacture of many of the items.

It was recommended that an attempt be made to utilize the Company's existing material requirements planning system, to replace the current laborious process.

C. PROVIDING VALID STATISTICAL FORECASTS

Utilizing the Company's existing material requirements planning system to replace the current makeshift system offered some significant benefits.

It would preclude the need for the current laborious processes, and provide the material planners with the same visibility of projected service support requirements that they now have for manufacturing requirements. This would allow the material and inventory managers to concentrate on refining the established guidelines, and responding to exceptional requirements. However, before the mechanized system could be used, a method of providing valid usage data to the statistical forecasting algorithm had to be provided. The statistical forecasts resident in the system had been previously rejected as inaccurate by the Division material planners. The reason for the rejection was unclear. It was determined that an analysis of the various possibilities for providing a valid statistical forecast was required.

1. Evaluation of Statistical Forecasts as Predictors

An empirical comparison of the sample data revealed the two predictors (statisical forecasts and average regional usage), to be so far apart that it seemed there must be a problem in the data inputs. the disparity was caused by variations in the periods covered by the two reports and the methods of handling cancelled orders. A

total of nine part numbers in the sample were affected by these administrative problems. The remaining ninety two items showed absolute correlation in the raw usage data. This supports the Service Managers' claim that the data is being input correctly.

Results of the regression analysis are shown in Appendix D. These results were interpreted for the Company in the Memorandum of 20 April, 1982 (Appendix C)

a. The Exponential Smoothing Factor

A review of the sample data with inventory and service personnel, revealed that most sporadic increases in usage were a result of some special set of circumstances or errors in ordering. In either case, it is not desirable to allow these instances to overly influence future stocking levels.

The over responsiveness to sporadic changes in usage is a funtion of the Exponential Smoothing Factor as described in Appendix E. It is designed to increse responsiveness to changing market trends [Ref. 5: sec.207]. This responsiveness is neither necessary or desirable when responding to the relatively slow changes expected in dealing with mechanical or electronic failure rates, as approximated by either of the commonly used exponential or Weibull distributions [Ref. 12: pg.27].

The skewing can be reduced by reducing the exponential smoothing factor used in the computations, as shown in Appendix E. A discussion with personnel in the Management Information Section resulted in reducing the exponential smoothing factor from 0.2 to 0.154 which approximates a twelve month moving average [Ref. 14: p.8].

The selection was an arbitrary one, to be used on a trial basis only. However, it should provide a fairly stable input to the material requirements planning process without any program changes. Continued monitoring of both

input and output data should continue, and further adjustment of the exponential smoothing factor will probably be required. This will allow the material and inventory managers to concentrate on refining the established guidelines and responding to exceptional circumstances.

IV. IMPLEMENTATION

A. COORDINATION WITH MANUFACTURING DIVISION

The series of implementation planning meetings resulted in an agreement to utilize the modified Statistical Forecast as an input to the material requirements planning process. Procedures for handling the service support inventory requirements within the Material Planning Section of the Manufacturing Division were discussed.

Concern was expressed over the validity of the lead time computations. If the statistical input is made directly to the Manufacturing Division's material requirements planning process, the lead times provided will be those utilized for a normal production run schedule. This would not allow for the exceptionally long lead times experienced with the small quantity orders for out of production equipment commonly received from the service organization. It would also preclude the automatic separation of allocations to the regional inventories. An alternative proposal was to run a separate material requirements planning process for Service Division with specifically designated lead times. The resultant orders would be submitted directly to Purchasing, or placed into the Manufacturing Division's material requirements Planning process. This system would preclude consolidation of orders and would cause unnecessary duplication.

The Memorandum of 20 April, 1982 (Appendix C) presented arguments against the over emphasis of lead time. The Statistical Forecast is only an educated guess at future demand. A great deal of effort and expense can be wasted trying to meet "required delivery schedules" when they are only predictions of average or routine demand.

Concern for lead time in this instance is greatly unwarranted. There is a fallacy in considering statistical forecasts in the same way we do demand. The statistical demand is based on historical data. Therefore, the initial demand will always appear to be late by the amount of lead time prescribed. The lead time value helps by speeding the response to any increased demand but it equally slows the responsiveness to decreasing trends. Attempts to gain an edge on this unpredictable demand by adding to lead times will only add expense. Efforts to improve lead times should be limited by the level of accuracy of the Statistical Forecasts.

1. <u>Adjusting Stocking Levels</u>

One very valid concern expressed by the material planners is that the Statistical Forecast will be allowed to run the system unchecked. Adjustment of stocking levels for specific equipments, can be accomplished in two ways. The economic order quantity computations in the Material Requirements Planning process, if left intact, will vary stocking levels in accordance with the relative cost and demand of each item. Desired manipulation of stocking levels to accommodate subjective evaluations of the importance of an item or to compensate for the fact that it is out of production, should be made by varying the safety factor. The current safety stock multipliers are set to yield a stock out level of two percent for items valued at less than one dollar, and five percent for all other items. This approximates the breakdown recommended in the initial study. If the resulting inventory levels are not satisfactory, these values may also be arbitrarily set. Safety factors could be applied to each region separately, or an agregate report could be requested for the Division, with the safety stock allocated only to the home office.

Unfortunately, time restrictions precluded indepth evaluation of optimal exponential smoothing factor or safety factor settings.

2. *A Compromise Proposal*

A compromise plan was developed, which would negate any lead time computations by the Service Division. Instead, planned orders from Service are inserted into the Manufacturing material requirements planning process prior to lead time and economic order quantity computations. The key to this plan was the MARK IV data base access program which was under development as a result of proposals made in the Memorandum of 3 March,1982 (Appendix B). This program will also flag significant aberrations in the data, for management review and adjustment.

Further discussions centered on the relative workloads and the internal processes of material procurement which are beyond the scope of this study.

V. CONCLUSIONS AND APPLICATIONS

A. CONCLUSIONS

My primary intent was to gain an understanding of a major corporation's service support capabilities, in relation to Navy contracting policies. I have reached three conclusions.

First, commercial firms face many of the same problems that are encountered in the Navy. Their data processing and management information systems are often too big and too complex, while the managers are too busy and without the requisite personnel assets to adapt them to specific needs.

Secondly, high inflation rates make holding costs the driving factor in any inventory model. Warehousing costs driven up by high utility rates and real estate values are out distancing relatively stable ordering costs, which have been aided by more efficient data processing. Express shipping rates reduced by increased competition among the carriers also enter the economic equation. The result is an overall trend to reduce and centralize inventories. Only a profit motivated desire to maintain customer satisfaction, prevented a reduction in the regional inventories.

The third conclusion has to do with the vagrancies and subjective nature of service support requirements. Machines don't break on schedule. Although a great deal of research and analysis of reliability trends has been done, complex machines such as the radiographic linear accelerators dealt with here, do not fit any one known model. The time and expense of building reliability models for even a few of the major components would be far beyond the economic value of such data. For the amount of money involved with this inventory, the Company was not inclined toward expensive

inventory management systems. The favored approach was to adapt the available material requirements planning and material control systems, with improved historical usage predictions, to provide satisfactory planning for a majority of parts. The resulting saving in manpower over the old manual system, can be utilized to handle exceptional requirements, and review and revise usage predictions as necessary.

The fact that many of the recommendations made in this report, have been accepted and utilized by the Company, attribute to the value of the exercise and the validity of the recommended improvements.

B. APPLICATION

The Navy would do well to remember these underlying economic motivations, and the inherent problems in determining service support inventory levels, when contracting for commercial support of our weapons systems.

Assuming that a contractor will be an ultimate and endless source of repair parts is a dangerous misconception. Large financial incentives would be necessary for continued parts support beyond the termination of scheduled production.

On site stocking of spare parts is extremely expensive if the cost of capital is considedred at current high interest rates. Centralized stocking and utilization of air freight express shipments provides a viable alternative.

Documentation of service support performance and utilization of this data in selecting vendors for follow-on procurements, could provide significant incentives for improved support.

APPENDIX A

MEMORANDUM OF 15 DECEMBER 1981

From: Gary W. Strawn

To: Mr. Ed Kelly

Subj: Analysis of various inventory and shipping techniques utilized in support of Field Service operations.

A. OBJECTIVE

The objective is to determine if the desired ninety five percent success rate can be achieved at a reduced cost. Success is defined as overnite response to critical (priority First Aid) service demands. The analysis will include varying the quantities and location of spare parts inventories and/or the modes, distances or frequencies of express shipments. The criterion used will be fixed effectiveness at minimum cost.

B. ALTERNATIVES

Alt 0: Most parts carried in Palo Alto, with some items carried in Atlanta and Chicago (this system was in effect at the time of the sample).

Alt 1: Four months projected demand stocked at each regional site (Palo Alto, Chicago, Atlanta).

Alt 2: Entire four months projected demand stocked at Palo Alto.

Alt 3: One year projected demand stocked at each regional site.

Alt 4: A combination of the other alternatives based on a hypothetical "ABC" breakdown of the inventory.

The possibility of placing inventory at other than the three established regional stock points was rejected because of undesirable warehousing costs and additional inventory management requirements.

C. ANALYSIS OF SHIPPING COSTS

Company policy states that the mode of shipment for priority one and two requirements is dictated by the the field service personnel. More than half of the orders received by the service support organization are classified as "First Aid". Forty five percent are priority two and and the remaining five percent are priority three. Although company policy dictates the use of certain common carriers for priority three shipments, research with these companies revealed that they will only accept consignments of more than 100 pounds. For this and other sound reasons of expediency, accountability and consolidation of effort, ninety nine percent of all shipments were made via air freight express companies which guarantee "next day delivery". In some cases this is defined as "prior to the end of the working day, following the day of shipment". Since we could not discern any significant difference in actual delivery times of the three primary shipping modes used (Federal Express "Priority One", Profit by Air "Express" and United Parcel Service "Blue Label Air"), they all will be assumed to meet the twenty four hour delivery requirement. UPS "Standard, Common Carrier", stipulates five to seven day delivery times. This mode costs approximately twenty percent of the average air frieght express rate, and was utilized to compute optimum priority three (stock replenishment) costs.

Changes in company policies and the performance of the air freight express industry have been frequent. Therefore, it was decided that only shipping data from the last half of

Fiscal Year 81 and the first two months of Fiscal Year 82 would be used. Data was available only for shipments from Palo Alto. Service records for each machine were screened for any requirement placed during the month of July 1981 and the week of 30 October through 4 November 1981. Data from the two periods, as shown in Enclosure 1, were compared to determine if significant variances were present. Statistical confidence intervals (ninety five percent confidence) were computed on the sample means for both the costs and the weight of shipments, plus the number of shipments to each region. The variations in the means of the two samples were well within the confidence intervals. Therefore, the two samples were combined to provide an overall sample of 347 shipments.

The mode of shipment specified by the service personnel is usually based on the reputed reliability and expediency of the particular carrier in the destination area. Except in localized or hand carried situations, it was assumed that the mode of shipment would be the same for any destination, regardless of origin.

Average shipping costs for the sample data were computed as cost per pound, cost per shipment, cost per item shipped, and cost per value of unit shipped. The difference in the shipping costs to all points in the U.S., with Palo Alto as the origin, are compared with projected costs utilizing the same mode of shipment from the appropriate regional stock points: Atlanta and Chicago. They approximate the expected shipping costs for alternatives One, and Two. The results are displayed in Figure A.1 It should be noted that fifteen out of 347 shipments in the sample were made by carriers other than the three primary ones. This includes six shipments to overseas locations. Since none of the other modes accounted for more than one percent of the total, and it is company policy to continue to handle all foreign sales from

the home office, the rate structures of the three primary carriers were utilized for all computations.

COST:	to all regions	intra-regional
per pound	$ 1.91	$ 1.94
per shipment	$42.15	$42.70
per item	$25.39	$26.70
per $ value	$ .20	$ .21

Cost were calculated for shipments from Palo Alto to points in all regions, and then projected for the same mode of shipment from the appropriate regional stock points.

Figure A.1 Costs of Shipments from Various Stock Points.

The data displayed in Figure A.1 appeared questionable because the intra-regional shipping costs were higher than the costs for the greater shipping distances expected in the centralized case. However, the differences were within the variation limits permitted for the ninety five percent confidence level. Therefore, the costs should be considered as essentially equal.

One finding of the comparisons in Figure A.1 was the fact that there is no significant savings in cost by reducing the distance of a shipment, assuming the same mode of shipment is used. A comparison of rate tables for the three primary air freight companies showed that only ten percent of the total cost of any given shipment is determined by the distance to be covered. The relative size and remoteness of the destination, and consolidation of items into the smallest possible number of shipments/pick-ups can cause shipping cost to more than double or cut them in half, for any given distance.

In order to test the hypothesis that similar modes of shipment have been utilized regardless of regional destinations, the sample shipping costs from Palo Alto were separated between destinations inside and outside of the western region. The results are shown in Figure A.2

COST:	intra-regional	inter-regional	Average
per pound	$ 1.49	$ 2.26	$ 1.62
per shipment	$26.88	$52.82	$42.15
per item	$15.53	$33.00	$25.39
per $ value	$ .13	$ .26	$ .20

Shipments from Palo Alto were divided into two groups: those with destinations inside the western region, and those destined for other regions.

Figure A.2 Costs of Shipments Originating in Palo Alto.

The significantly lower shipping costs within the western region were attributed to two primary factors. First, approximately fifteen percent of the shipments were being hand carried by the service personnel. Second, thirteen percent were sent via United Parcel Service Standard Common Carrier rates, which are approximately twenty percent of the average air freight express rates.

D. ANALYSIS OF INVENTORY CARRYING COSTS

The usual discussion and analysis of inventory costs includes three basic categories: inventory carrying (holding) cost, ordering (acquisition) or set up costs, and stockout cost. Each of the three types of cost has a unique nature and a number of different factors involved.

First, holding cost generally includes the handling cost associated with moving a product into and out of inventory, and the storage costs such as rent, heat, light, etc. Other components of carrying costs are insurance, taxes, obsolescence and deterioration. The major component of holding costs is the opportunity cost of capital. This cost is set in relation to the Company's designated Return on Investment (ROI). Due to the current high interest rates, the before tax ROI is set at thirty percent. Therefore, the total holding cost is set at thirty six percent of the average value of inventory.

Stockout cost will not be a factor in this analysis, since any alternative which does not provide the requisite ninety five percent fixed effectiveness will be rejected outright.

The various measures of shipping costs (cost per pound, cost per item, etc.) demonstrated essentially the same relationships. Therefore, the selection of cost per shipment to relate company shipping records, was made on the grounds that it was most convenient. The following analysis of the five alternatives was made utilizing the sample monthly averages for shipments in zone and out of zone and applying them to projected demands from each of the three regional centers.

E. EVALUATION OF ALTERNATIVES

Inventory figures were drawn from Nov, 1981 data. They are a monthly figure and not a true annual average. The wide variations in data caused by changes in support procedures during the year make it undesirable to use an annual average to evaluate the current practice. The month of November is taken to be a good representation of current inventory value. Holding costs were computed by multiplying inventory value by thirty six percent.

1. Alternative 0

(most parts carried in Palo Alto, some items carried in Atlanta and Chicago: the system in effect at the time of the sample)

Annual Shipping Costs:

From Palo Alto to the Western region	$	37,740
From Palo Alto to the other regions	$	145,788
From Atlanta/Chicago to their regions	$	25,488
Cost of moving inventory to Atlanta/Chicago	$	7,740
Sub total:	$	216,756

Annual Inventory Costs:

	Palo Alto	Chicago	Atlanta	Total
Value (Inv):	$1,767,704	$202,750	$226,842	$2,197,296
Holding Cost:	$ 636,373	$ 72,990	$ 81,663	$ 791,027
			Sub Total:	$ 791,027

Total Annualized Cost of Alternative 0 : $1,007,783
(equals holding cost plus shipping cost)

2. Alternative 1

(four month's demand stocked at each regional site)

Approximately sixty percent of the total 4877 line items show activity in the inventory records each month. Consequently, it seems reasonable to assume that four months demand stock with one week refill time, could cover eighty percent of the monthly intra-regional requirements.

Annual Shipping Costs:

From Palo Alto to the Western region	$	37,740
From Palo Alto to the other regions (20%)	$	39,300
From Atlanta/Chicago to their regions (80%)	$	79,668
Cost of moving inventory to Atlanta/Chicago	$	24,216
Sub total:	$	180,924

If the intra-regional fill rate is ninety percent:

shipping costs are $ 171,300

If the intra-regional fill rate is sixty percent:

shipping costs are $ 200,100

Annual Inventory Costs:

	Palo Alto	Chicago	Atlanta	Total
Value (Inv)	$ 316,714	$240,673	$406,507	$ 963,894
Holding Cost:	$ 114,017	$ 86,642	$146,343	$ 347,002

Sub Total: $ 347,002

Total Annualized Cost of Alternative 1: $ 527,926

(ninety percent intra-regional fill rate) $ 518,302

(sixty percent intra-regional fill rate) $ 547,102

3. <u>Alternative 2</u>

(entire four month's demand stocked at Palo Alto)

Annual Shipping Costs:

From Palo Alto to the Western region $ 37,740

From Palo Alto to the other regions $ 195,852

Sub total: $ 233,529

Annual Inventory Costs:

Value (Inv) $ 963,894

Holding Cost: $ 347,002

Sub total: $ 347,002

Total Annualized Cost of Alternative 2: $ 580,531

4. Alternative 3

(one year's demand stocked at each regional site)

Annual Shipping Costs:

(Assuming stock will cover 98% of the regional demand)

From Palo Alto to the Western region	$	37,740
From Palo Alto to the other regions (2%)	$	1,932
From Atlanta/Chicago to their regions (98%)	$	191,940
Cost of moving inventory to Atlanta/Chicago	$	29,664
Sub total:	$	261,276

Annual Inventory Costs:

	Palo Alto	Chicago	Atlanta	Total
Value (Inv)	$ 950,142	$1,219,521	$722,016	$2,891,949
Holding Cost:	$ 342,051	$ 439,028	$259,926	$1,041,112
			Sub total:	$1,041,112

Total Annualized Cost of Alternative 3: $1,302,388

5. Alternative 4

(a combination of the other alternatives based on a hypothetical "ABC" breakdown of the inventory)

In order to test the potential value of this option, it was assumed that the classical standard of twenty percent of the inventory by value can be selected such that it will fill eighty percent of the average monthly requirements.

Category A (20% of the inventory / 80% of the demand: 20% of one year's demand stock carried at each region)

Inventory Value (20% of alt.3):	$578,390	
Inventory Holding Costs:		$208,222
Shipping Costs (80% of alt.3):		$209,021
Sub Total:		$417,243

Category B (30% of the inventory / 15% of the demand: 30% of four month's demand stock carried at Palo Alto)

Inventory Value (30% of alt.2):	$289,168	
Inventory Holding Costs:		$104,101
Shipping Costs (15% of alt.2):		$ 35,029
Sub Total:		$139,130

Category C (50% of the inventory / 5% of the demand: Stock not carried, requisitions to be filled from manufacturing stock, procurement or fabrication)

Shipping Costs (5% of alt.2):	$ 11,676
Sub Total:	$ 11,676

Total Annualized Cost of Alternative 4: $568,049

F. CONCLUSIONS

The following table provides a quick comparison of the quantifiable costs of the alternatives considered.

Alt 0 (current mix)	$1,007,783
Alt 1 (4 month's stock at each region)	$ 527,926
Alt 2 (4 month's stock at Palo Alto)	$ 580,531
Alt 3 (1 year's stock at each region)	$1,302,388
Alt 4 (ABC breakdown)	$ 568,049

Alternative One appears to offer the lowest quantifiable cost. However, the ninety five percent confidence intervals allow approximately $53,000 variance in the computed costs. Therefore, neither alternatives One, Two or Four can be considered to offer a cost advantage. Alternative Three is considerably more expensive, but it calls for the tripling of inventories at all sites. This should lead to some offsetting increase in service support effectiveness. Only

Alternative Zero can be rejected based on cost and it has already been rejected by company management for being ineffective.

Effectiveness must then become the determining factor between the remaining alternatives. However, quantifying the relative effectiveness of these alternatives is beyond the scope of this study.

There is some tendency in logistics to emphasize cost. However, logistics has to contribute to the overall profitability of the company. Profit maximization is a vital concern and is usually the most important objective for overall efficiency of the organization. In this case, the external effects of company decisions, such as effects on customer relations may assume utmost importance. Concentrating on the cost factors of transportation and inventory alone, may be harmful to overall company goals.

Alternative Three has the potential of improving effectivness by some unknown factor, but this must be weighed against the aditional cost. Alternative Four offers the same potential for improved effectivness with the lower cost and advantages offered by Alternative One. It must be remembered, however, that this was a hypothetical case and the decision to do further investigation must be made by management based on the value of improved effectiveness, i.e. efficiency of service personnel and enhanced customer satisfaction (good will), leading to improved follow-on sales.

1. <u>Recommendations</u>

Alternative Four should be investigated further as the most promising alternative. Meanwhile, the Division should continue with the implementation of Alternative One.

Enclosure 1. Sample of Service Support Shipping Data

The following data was collected from the main office (Palo Alto, Ca.) shipping records for the month of July, and the week of Oct 30 through Nov 4, 1981.

Destination	Itms	Bxs/Lbs	Mode *	Rt/Cost	Area/Rt/Cost **
#Akron,Oh	-	1/2	P	5a/26.50	C/g 1a/24.00
Albany,Ga	4	1/7	O	-	A -
Albuquerque,NM	1	1/1	F	C/26.95	P-
# "	-	1/1	P	g3a/25.00	P-
Amarillo, Tx	1	1/20	P	4a/45.50	A/ 3a/43.00
"	1	1/1	P	4a/25.50	A/ 3a/24.00
"	1	1/13	P	4a/40.50	A/ 3a/39.00
"	1	1/5	P	4a/25.50	A/ 3a/25.00
"	1	1/1	O	-	A -
"	1	1/11	F	D/41.15	A/ C/39.86
# "	2	1/10	F	D/38.95	A/ C/37.70
Atlanta,Ga	1	1/45	F	E/80.32	A -
"	1	1/9	U	C/11.33	A -
"	3	1/2	U	C/ 3.61	A -
"	1	1/1	P	g 4a/25.50	A -
"	1	1/5	F	E/32.45	A -
# "	1	1/7	P	g5a/43.00	A -
# "	1	1/15	U	C/17.96	A -
Augusta,Ga	-	1/42	U	C/47.76	A/ A/42.19
"	1	1/7	P	g5a/35.00	A/g2a/30.50
"	-	1/4	P	g5a/26.50	A/g2a/24.50
"	2	1/28	U	C/32.30	A/ A/28.59
"	1	1/780	P	g5a/1016.00	A/g2a/638.0
# "	1	1/48	P	g5a/58.00	A/g2a/54.50
Baltimore,Md	1	1/44	F	E/79.51	C/ B/64.77
# "	-	1/3	F	E/29.57	C/ B/26.20
#Beach Grove,In	-	1/4	P	g5a/26.50	C/g1a/24.00
Belleville,Il	2	1/2	O	-	C -
Bethesda,Md	-	hand carry		-	C -
"	-	1/20	P	g5a/49.00	C/g3a/43.00
"	-	1/17	P	g5a/49.00	C/g3a/43.00
"	1	1/195	O	-	C -
Bethlahem,Pa	1	1/1	U	C/ 2.51	C/ B/ 2.38
Birmingham,Al	-	1/2	O	-	A -
Boca Raton,Fl	-	1/6	F	E/36.05	A/ B/31.95
# "	1	1/1	U	C/ 2.51	A/ B/ 2.38
Boise,Id	2	1/2	P	5a/26.50	P
# "	1	1/39	P	5a/68.00	P-
Boston,Ma	2	1/4	F	E/33.01	C/ B/29.20
"	2	1/9	U	C/11.33	C/ A/10.40
"	1	1/5	U	C/ 6.62	C/ A/ 6.26
"	1	1/1	F	E/28.70	C/ B/26.20
"	1	1/1	U	C/ 2.51	C/ A/ 2.38
"	1	1/5	F	E/34.45	C/ B/30.20
Bradenton,Fl	1	1/4	O	-	A -
# "	-	1/1	O	-	A -
Bridgeport,Ct	2	1/2	F	E/30.13	C/ C/28.07
#Carbondale,Il	-	1/35	P	11B/76.50	C/ 2b/50.50
Chatanooga,Tn	1	1/44	U	C/49.97	A/ B/44.13

Destination	Itms	Bxs/Lbs	Mode *	Rt/Cost	Area/Rt/Cost **
#Charlotte,NC	-	1/10	F	E/42.45	A/ A/37.20
Chester,Pa	2	1/7	U	C/ 9.13	C/ A/ 8.20
Chicago,Il	1	1/5	F	E/34.45	C -
"	5	1/2	F	E/30.13	C -
(Park Ridge)	4	1/2	O	-	C -
"	1	1/25	O	-	C -
"	2	1/5	P	g4a/25.50	C -
"	1	1/2	F	E/30.13	C -
"	1	1/1	P	g4a/25.50	C -
"	4	1/2	F	E/30.13	C -
"	1	1/20	P	g4a/45.50	C -
"	3	1/232	P	g4a/354.00	C -
"	1	1/6	P	g4a/33.50	C -
"	2	1/2	U	B/ 3.35	C -
# "	stk	1/35	P	g4a/57.50	C -
# "	1	1/2	F	E/30.13	C -
# "	1	1/1	P	g4a/25.50	C -
# "	stk	1/35	P	g4a/57.50	C -
Cincinati,Oh	2	1/2	F	E/30.13	C/ A/25.67
Cleveland,Oh	1	1/1	U	B/ 2.38	C/ A/ 2.38
"	1	1/1	U	B/ 2.38	C/ A/ 2.38
Corpus Cristi,Tx	1	1/4	F	E/33.01	A/ C/30.32
"	2	1/1	P	5a/26.50	A/ 3a/25.00
"	1	1/7	F	E/37.65	A/ C/34.75
Cornwall,Pa	1	1/2	U	C/ 3.61	C/ B/ 3.35
Cranford,NJ	1	1/4	F	E/33.01	C/ B/29.20
"	3	1/9	F(sd)	E/23.39	C/ A/20.70
"	2	1/8	F	E/30.25	C/ B/35.45
Dallas,Tx	1	1/2	U	B/ 3.35	A/ A/ 3.35
# "	-	1/42	P	g4a/65.50	A/g2a/51.50
# "	2	1/1	P	g4a/25.50	A/g2a/24.50
Danville,Pa	1	1/2	F(sd)	E/18.46	C/ B/17.91
Dayton,Oh	1	1/2	F	E/30.13	C/ A/25.67
"	1	1/165	P	g5a/282.00	C/g1a/96.00
"	1	1/22	F	E/57.83	C/ A/47.91
"	5	2/26	F	E/62.85	C/ A/51.27
"	4	3/161	P	g5a/282.00	C/g1a/96.00
# "	1	1/48	P	g5a/78.00	C/g1a/38.25
Denver,Co	1	1/8	F	C/36.60	P -
"	1	1/10	F	C/39.70	P -
"	1	1/6	F	C/33.10	P -
Detroit,Mi	1	1/2	F	E/30.13	C/ A/25.67
Dothan,Al	1	1/1	P	g6a/27.00	A/ 1a/24.00
"	1	1/1	P	g6a/27.00	A/ 1a/24.00
"	1	1/5	F	E/34.43	A/ A/30.42
Duarte,Ca	1	1/180	P	g1b/116.00	P -
#Duluth,Mn	-	1/2	U	B/ 3.35	C/ B/ 3.35
# "	-	1/1	P	11a/50.50	C/ 8a/49.00
# "	2	2/1	P	11a/50.50	C/ 8a/49.00
Dunedin,Fl	2	1/36	P	g5c/78.00	A/g2b/52.50
"	1	1/30	P	g5c/68.00	A/g2b/48.50
Durham,NC	2	1/6	F	E/36.05	A/ B/31.95
East Chicago,Il	1	1/1	P	g4c/35.50	C -
"	3	1/18	P	g4c/55.50	C -
East Meadow,NY	2	1/4	P	g5b/29.50	C/g2b/27.50
East Pt,Ga	1	1/5	P	g4a/25.50	A -
" (Atlanta)	-	1/9	F	E/40.85	A -
"	1	1/5	P	g4a/25.50	A -
"	7	1/9	F	E/40.85	A -

Destination	Itms	Bxs/Lbs	Mode*	Rt/Cost	Area/Rt/Cost**
Eureka,Ca	1	hand carry		-	P -
"	2	"		-	P -
"	1	"		-	P -
"	2	1/2	P	g2a/24.50	P -
#Evansville,Il	1	1/22	P	5c/63.00	C/ 1c/43.00
Farmington,NY	3	1/5	F	E/37.45	C/ C/34.45
Flint,Mi	4	1/3	U	B/ 4.32	C/ A/ 4.32
Fort Smith,Ar	1	1/5	F	D/33.20	A/ B/30.20
Fort Wayne,In	3	1/28	F	E/66.50	C/ A/53.90
"	2	1/28	F	E/66.50	C/ A/53.90
"	1	1/80	P	5a/112.00	C/g1a/43.00
Fountain Vlly,Ca	1	1/165	P	g1b/99.00	P -
Fresno,Ca	1	1/22	P	g1a/33.00	P -
Fullerton,Ca	1	1/4	U(si)	/ 1.87	P -
Galviston,Tx	3	1/2	P	6a/27.00	A/ 5a/26.50
Goose Creek,SC	1	1/1	P	5b/29.50	A/ 1b/27.00
" (Charleston)	1	1/5	U	C/ 6.92	A/
Grand Rapids,Mi	1	1/2	P	5a/26.50	C/ 2a/24.50
Greenville,SC	1	1/5	F	E/34.45	A/ A/28.70
"	1	1/34	P	5a/63.00	A/g1a/35.00
"	1	1/8	O	-	A -
Hartford,Ct	3	2/500	P	g5a/635.00	C/g4a/575.0
"	1	1/3	F	E/31.57	C/ C/29.20
"	1	1/1	F	E/28.70	C/ C/26.95
"	1	1/6	F	E/36.05	C/ C/33.10
Hershey,Pa	1	1/1	F	E/28.70	C/ B/26.20
Highland Pk,Mi	1	1/13 -	P	g5a/43.00	C/g1a/29.50
Hill AFB,Ut	1	1/5	P	2b/27.50	P -
Hollywood,Fl	1	1/1	U	C/ 2.51	A/ B/ 2.38
# "	-	1/22	P	g5b/56.00	A/g2b/46.50
Houston,Tx	4	1/3	F	E/31.57	A/ B/28.20
Irvine,Ca	5	1/29	P	1b/37.00	P -
"	1	1/2	U(si)	/ 1.50	P -
Iowa City,Io	1	1/6	P	5b/38.00	C/ 1b/30.50
"	1	1/2	P	5b/29.50	C/ 1b/27.00
"	1	1/6	F	E/36.05	C/ A/30.40
Jackson,Ms	1	1/4	F	E/33.01	A/ A/27.42
Johnstown,Pa	1	1/3	U	C/ 4.72	C/ B/ 4.32
"	1	1/2	F	F/31.20	C/ E/30.13
"	1	1/11	O	-	C -
Kent,Wa	3	2/32	U(si)	/ 7.04	P -
"	4	1/1	U(si)	/ 1.32	P -
"	1	1/2	P	g2a/30.50	P -
Knoxville,Tn	1	1/3	U	C/ 4.72	A/ B/ 3.36
Lakeland,Fl	1	1/2	P	5b/29.50	A/ 2b/27.50
"	3	1/6	U	C/ 8.03	A/ B/ 7.23
"	3	1/1	U	C/ 2.51	A/ B/ 2.30
Lancaster,Pa	2	1/2	U	C/ 3.61	C/ B/ 3.35
"	2	1/2	U	C/ 3.61	C/ B/ 3.35
Lauderdale Lks,Fl	1	1/2	P	g5b/29.50	A/g2a/27.50
"	1	1/192	P	g5b/285.00	A/g2a/181.5
"	1	1/1	U	C/ 2.51	A/ B/ 2.38
Little Rock,Ar	1	1/6	O	-	A/ -
Los Angeles,Ca	1	1/5	P	g1a/24.00	P -
Madison,Ws	4	1/38	P	g5a/68.00	C/g1a/35.50
"	1	1/1	F	E/28.70	C/ A/24.80
"	2	1/1	P	g5a/26.50	C/g1a/24.00
#Medford,Or	1	1/8	P	g2a/30.50	P -
Memphis,Tn	1	1/192	P	g5a/282.00	A/g2a/178.5
"	5	1/8	F	E/39.25	A/ A/37.80
"	1	1/120	P	g5a/282.00	A/g2a/178.5
"	2	1/5	F	E/34.45	A/ A/28.70
Miami,Fl	1	1/1	F	E/28.70	A/ A/26.20
# "	1	1/2	F	E/30.13	A/ A/27.20

Destination	Itms	Bxs/Lbs	Mode *	Rt/Cost	Area/Rt/Cost **
Milwaukee,Wi	1	1/1	P	g5a/26.50	C/g1a/24.00
"	1	1/5	U	B/6.26	C/ B/ 6.26
"	1	1/44	F	E/81.51	C/ A/63.89
#Mineola,NY	1	1/2	F	E/30.13	C/ C/28.07
Modesto,Ca	1	hand carry		-	P -
"	3	"		-	P -
"	2	"		-	P -
"	4	"		-	P -
Mongomery,Al	1	1/18	U	C/21.27	A/ A/18.88
Mt Holly,NY	1	1/5	U	C/ 6.92	C/ A/ 6.26
Muncie,In	1	1/1	U	B/ 2.38	C/ A/ 2.38
"	1	1/35	P	6a/68.50	C/ 4a/57.50
"	1	1/8	F	F/41.10	C/ D/37.85
Nashville,Tn	1	1/5	F	E/34.45	A/ A/28.70
"	12	1/49	P	g5a/78.00	A/g1a/38.25
# "	1	1/4	F	E/33.01	A/ A/27.42
# "	1	1/79	F	E/117.16	A/ A/84.06
#New Brunswick,NJ	-	1/7	P	g5b/38.00	C/g2b/33.50
New Orleans,La	2	1/6	P	g5a/35.00	A/g2a/30.50
# "	-	1/2	P	g5a/26.50	A/g2a/24.50
#New York,NY	1	1/10	P	g5a/35.00	C/g2a/30.50
Newark,NJ	1	1/12	F	E/46.73	C/ A/40.32
"	2	1/2	U	C/ 3.61	C/ A/ 3.35
"	1	1/5	F	E/34.45	C/ A/28.70
"	1	1/4	F	E/33.01	C/ A/27.42
"	1	1/1	F(si)	E/17.77	C/ A/17.26
#Newport Beach,Ca	1	1/1	U(si)	/ 1.32	P -
Newport News,Va	1	1/2	F	E/30.13	A/ B/27.20
"	3	1/30	F	E/69.70	A/ B/58.45
Newport Richey,Fl	1	1/1	P	5b/29.50	A/ 2b/27.50
"	2	1/2	P	5b/29.50	A/ 2b/27.50
"	1	1/2	P	5b/29.50	A/ 2b/27.50
"	3	1/3	F	E/31.57	A/ B/28.80
Nimbus,Ca	12	1/2	P	1b/24.00	P -
Ocala,Fl	1	1/3	F	F/32.70	A/ D/31.85
"	2	1/45	F	F/87.80	A/ D/74.11
"	1	1/4	U	C/ 5.82	A/ B/ 5.29
Oklahoma City,Ok	2	1/30	F	D/63.52	A/ C/60.53
# "	1	1/170	P	g4a/247.50	A/g3a/211.0
# "	1	1/10	F	D/40.95	A/ C/39.70
Onasbruk,Germany	1	1/2	O	-	P -
Orange,Ca	1	1/2	P	g1b/27.00	P -
Orlando,Fl	1	1/200	P	g5a/272.50	A/g2a/166.5
"	1	1/192	P	g5a/272.50	A/g2a/166.5
Palo Alto,Ca	1	hand carry		-	P -
Pensacola,Fl	1	1/38	F	E/69.17	A/ A/60.58
"	2	1/10	P	g5a/35.00	A/g2a/30.50
"	2	2/90	F	E/117.16	A/ A/84.06
"	9	1/3	P	g5a/26.50	A/g2a/24.50
"	1	1/43	F	E/80.63	A/ A/63.33
"	2	2/90	F	E/117.16	A/ A/84.06
Philadelphia,P	1	1/6	U	C/ 8.03	C/ A/ 7.23
#Pinehurst,NC	1	1/20	P	5b/52.00	A/ 1b/32.00
Phoenix,Az	1	1/3	P	g2a/24.50	P -
"	1	1/2	F	B/27.20	P -
"	1	1/2	F	B/27.20	P -
"	1	1/3	F	B/28.20	P -
"	1	1/3	P	g2a/24.50	P -
"	2	1/3	P	g2a/24.50	P -
"	1	1/2	P	g2a/24.50	P -
"	2	1/1	P	g2a/24.50	P -
"	2	1/2	P	g2a/24.50	P -
"	2	1/11	P	g2a/37.50	P -
"	1	1/1	F	B/26.20	P -
"	1	1/1	F	B/26.20	P -

Destination	Itms	Bxs/Lbs	Mode *	Rt/Cost	Area/Rt/Cost **
Plymouth Mtg,Pa	1	1/2	F	E/30.13	C/ B/27.20
Pocatello,Id	13	1/15	P	7a/51.00	P -
"	1	1/5	P	7a/48.50	P -
Portland,Or	1	1/165	P	g2a/166.50	P -
"	1	1/2	P	g2a/24.50	P -
"	1	1/5	F	B/30.20	P -
"	1	1/2	F	B/27.20	P -
"	1	1/1	F	B/26.20	P -
"	1	1/1	F	B/26.20	P -
#Portland,Me	1	1/3	F	E/31.57	C/ C/29.20
Poughkeepsie,NY	1	1/192	P	5c/302.00	C/ 2c/231.0
Provo,Ut	1	1/1	U	B/ 2.38	P -
#Pueblo,Co	1	1/2	P	5a/26.50	P -
Racine,Wi	1	1/3	U	B/ 4.32	C/ B/ 4.32
Reading,Pa	2	1/2	U	C/ 3.61	C/ A/ 3.35
Reno,Nv	1	1/4	P	g1a/24.00	P -
Richmond,Va	1	1/4	P	5a/26.50	A/ 2a/24.50
Rochester,Mn	1	1/1	U	B/ 2.38	C/ B/ 2.38
"	1	1/1	P	g6a/27.00	C/g1a/24.00
#Rochester,NY	1	1/1	P	5a/26.50	C/g4a/25.50
# "	-	1/2	P	5a/26.50	C/g4a/25.50
Rye,NY	2	1/2	F	E/31.20	C/ C/28.07
"	3	1/1	F	E/28.70	C/ C/26.95
"	4	1/24	F	E/59.65	C/ C/52.47
"	1	1/25	F	E/61.05	C/ C/53.58
Sacramento,Ca	1	1/24	P	g1a/33.00	P -
"	1	1/1	P	g1a/24.50	P -
"	1	1/4	P	g1a/24.00	P -
"	4	1/22	P	g1a/33.00	P -
"	4	hand carry		-	P -
"	1	1/4	U(si)	/ 1.87	P -
Saginaw,Mi	1	1/10	P	g5a/35.00	C/g1a/27.50
St. Louis,Mo	1	1/1	F	E/28.70	A/ B/26.20
# "	1	1/2	P	g5a/26.50	A/g2a/24.50
St. Petersberg,Fl	1	1/1	F	E/28.70	A/ B/26.20
"	2	1/1	O	-	A/
#Salem,Or	-	1/2	U(si)	/ 1.50	P -
Salisburg,Md	1	1/7	F(si)	E/37.65	C/ B/33.70
Salt Lake City,Ut	1	1/140	P	g2a/178.50	P -
"	1	1/6	P	g2a/30.50	P -
San Diego,Ca	1	3/37	P	g1a/35.50	P -
"	1	2/230	P	g1a/126.00	P -
"	1	1/2	P	g1a/24.00	P -
# "	-	1/3	U(si)	/ 1.39	P -
San Francisco,Ca	1	hand carry		-	P -
"	4	"		-	P -
"	1	1/10	U(si)	/ 2.00	P -
San Jose,Ca	1	hand carry		-	P -
"	3	"		-	P -
"	2	"		-	P -
San Juan,PR	8	1/41	F	E+/88.95	P -
San Rafael,Ca	1	hand carry		-	P -
"	1	"		-	P -
Santa Cruz,Ca	1	"		-	P -
"	1	1/5	U(si)	/	P -
#Santa Fe Spngs,Ca	1	1/17	U(si)	/	P -
Santa Maria,Ca	1	1/1	U(si)	/	P -
Santa Rosa,Ca	1	hand carry		-	P -
Sao Paulo,Brazil	4	1/4	O	-	P -
Scranton,Pa	2	1/22	P	5a/53.00	C/ 2a/43.50
Seattle,Wa	3	1/1	U(si)	/ 1.32	P -
"	1	1/5	P	g2a/24.50	P -
# "	1	1/10	U(si)	/ 2.97	P -
# "	-	1/9	P	g2a/30.50	P -

Destination	Itms	Bxs/Lbs	Mode *	Rt/Cost	Area/Rt/Cost **
Seoul,Korea	1	1/48	O	-	P -
"	1	1/73	O	-	P -
"	1	1/2	O	-	P -
Sioux Falls,SD	1	1/1	O	/	C/
#South Bend,In	1	1/35	F	E/73.90	C/ A/58.95
Spokane,Wa	1	1/1	O	-	P -
"	1	1/4	F	C/30.32	P -
"	2	1/2	F	C/28.07	P -
"	1	1/1	F	C/26.95	P -
# "	-	1/12	P	g3a/39.00	P -
# "	1	1/3	F	C/29.20	P -
Stockton,Ca	5	hand carry		-	P -
Summit,NJ	2	1/2	F	E/30.13	C/ A/25.67
"	2	1/2	F	E/30.13	C/ A/25.67
Syracuse,Ny	4	1/10	P	5a/35.00	C/g3a/32.00
Toledo,Oh	2	1/3	P	g5a/26.50	C/g1a/24.00
Torrance,Ca	1	1/2	P	g1a/24.00	P -
"	1	1/1	P	g1a/24.00	P -
Tucson,Az	2	1/18	F	C/48.32	P -
"	3	1/7	P	g3a/32.00	P -
"	3	1/7	P	g3a/32.00	P -
"	1	1/4	F	C/30.32	P -
Tulsa,Ok	2	1/9	F	D/39.40	A/ B/37.20
# "	-	1/1	P	g4a/25.50	A/g3a/25.00
# "	1	1/1	F	D/27.70	A/ B/26.20
Walla Walla,Wa	1	1/1	P	9a/49.50	P -
"	1	1/192	P	9a/264.00	P -
"	2	1/10	P	9a/51.00	P -
"	1	1/13	P	9a/52.00	P -
Walnut Creek,Ca	1	1/2	P	g1a/27.00	P -
Washington,DC	6	1/2	F	E/30.13	C/ B/27.20
West Jordan,Ut	1	1/10	F	B/38.95	P -
"	1	1/3	F	B/28.20	P -
"	1	1/6	F	B/31.95	P -
"	5	1/49	P	g2b/57.50	P -
"	2	1/5	F	B/30.20	P -
# "	2	1/4	P	g2b/27.50	P -
# "	1	1/4	F	B/29.20	P -
# "	1	1/4	F	B/29.20	P -
Wst Palm Beach,Fl	1	1/3	F	E/31.57	A/ B/28.20
Wilmington,Del	2	1/25	F	E/61.05	C/ A/49.97
Wilmington,NC	2	1/2	O	-	A/
"	1	1/1	U	C/ 2.51	A/
"	2	1/3	P	12a/51.00	A/g2a/24.50
"	1	1/1	F	D/30.70	A/ B/29.20
Youngstown,Oh	1	1/20	P	5a/49.00	C/g1a/32.00

* F= Federal Express: Priority One (unless otherwise noted)
P= Profit By Air: Express " " "
U= UPS: Blue Label Air " " "
O= Other

** A= Atlanta
C= Chicago
P= Palo Alto

# Denotes data collected for the week of Oct 30 through Nov 4, 1981.

APPENDIX B

MEMORANDUM OF 3 MARCH 1982

From: Gary W. Strawn

To: Mr. Ed Kelly

Subj: Material Planning for Medical Group Service Support

A. BACKGROUND

The intent of the this study is to investigate the posibilities of adapting or modifying the existing KMS MRP capabilities to the highly volatile and unpredictable demands of service support. The material managers in the service support section have found the system to be unsatisfactory in computing inventory requirements to meet the unscheduled needs of the service organization. In order to make any improvement in the cost effectiveness of the MRP for service support, we first had to analyze how the current inventory quantities were being determined, and what problems were causing the continuing deficiencies.

B. EVALUATION OF THE CURRENT PROCESS

The current process for determining stock allocations to maintain four month's average demand in inventory, at each of the three regional stock points, is complicated. It is a time consuming manipulation of periodic usage listings and material control reports. The results are questionable.

Examples of the reports utilized in the current process may be seen in Enclosure 1 under part number 00-808202-01.

1. Fabricated Bills of Material

The inventory manager has applied a great deal of time, energy and ingenuity in creating a "bill of material" for each inventory site. These "bills of material", are actually an ingenious adaptation of the KMS report XHSL: "Single Level Explosion". The report was designed as a breakdown of an assembly into its component parts. It was to be used as a bill of material for an assembly in the preparation of factory planning documents and the analysis of possible component substitutions.

In the adapted report, as shown in Enclosure 1a, a fictitious part number "A31STOCK01" is substituted for an assembly number, and the explosion is an inventory listing for regional stock point, Unit 31, "Midwest". In this fabricated regional inventory report, each part number selected for inventory at a given site is listed. It includes the nomenclature, unit of issue, quantity required per four month inventory level and unit cost, for each part number. The date of the latest change is manually entered in the Engineering Change Order "ECO" column, and the date of the latest transaction date is entered automatically by the system in the Latest Change Date "LCD" column.

2. Projecting Inventory Requirements

The average monthly usage for the period 1 October '80 to 31 August '81 was 7.6, so the desired inventory figure rounded up to 32 was placed into the "QTY/ASY" column of Chicago's bill of material. This becomes the projected four month allocation figure shown in column "CURSH/ALLO" of the Combined Shortage and Prefill Report (Part Sequence), Unit 31. This figure is subtracted from the Projected Stores quantity three times, and the projected annual deficit figure "31-" appears in the "RSULT STRES" column next to Issue Day 960.

3. Placing Issues

When it has been determined that a projected shortage exists at a regional stock point, a transaction against the part number and the desired issue day must be manually entered on a KMS terminal or hand written on a transmittal sheet, as shown in Enclosure 1b. This action will cause a deck of issue cards to be printed, which are then compared with the relative demand dates and existing inventory shortages placed against each part number for the other regional inventories as they appear on the Combined Shortage and Prefill Report (Part Sequence) Unit 00, as shown in Enclosure 1c. When the part in question does not appear on the Division report, as is the case with our example, then it means that there is some in stock at one of the regional sites and no issue is made. This procedure effectively negates the policy of maintaining stock at each site.

4. Making Allocations

When an allocation is to be made, an issue card is submitted to the MRP system. Varying lot sizes are determined by the inventory manager. He makes what he calls an "ABC decision", which is based on the relative cost and lead time of an item. High cost and short lead time items are submitted in four month quantities, whereas low cost long lead time items are submitted in annual quantities. Others may be submitted semi-annually. This is currently a slow, arduous and apparently very subjective or arbitrary process.

5. <u>Problems Encountered with the Current Process</u>

a. Cumbersome Manual Operations

The inventory listings have to be inserted into the report structure under the appropriate regional stock point "assembly number". This has been done manually by sorting thousands of stock cards and then having them input into the system. The manhours required for the initial operation were estimated to be in excess of one hundred, and updating continues to consume approximately four manhours per week. Being a very dedicated worker, the inventory manager has been taking a great deal of the manual sorting work home and doing it after hours. With the existing system, such a worker becomes invaluable, which is a separate problem to be discussed later.

b. Inacuracies in the Existing Usage Data

A major problem is the inherent inaccuracy of determining the desired inventory quantities from the existing usage data. Currently, a four month average demand for each part number in the regional inventory is manually computed by the inventory manager. He utilizes an existing Cobol program which accesses the Internal Revenue Service (IRS) data base. The data base was designed for computation of inventory values for tax purposes. Therefore, the report displays the monthly usage of each part number by stock point (unit) for the current fiscal year. Although twelve monthly columns are printed on each report, only those in the current fiscal year are computed. The others are left blank.

The inventory manager chose to utilize the August 1981 report with ten months of computed data for his initial computations. It is shown in Enclosure 1d, as report number 068 AB9XRN-01: "Part Usage by Region". The

average monthly usage figure is multiplied by four and, if less than one, rounded to the nearest half. The resulting figures are then inserted manually into the "QTY/ASY" column of each regional "bill of material" as the desired level of inventory. Because the usage report reverts back to zero at the begining of the new fiscal year, the initial usage figures will have to be used for nearly a year before realistic new averages can be computed. The existing computations are time consuming, unsophisticated and of very questionable validity.

The calculated inventory quantities have to be manually inserted into the fabricated "bills of material". KMS then manipulates the data base so that this quantity appears in the "CURSH/ALLO" (Current Shortage / Allocation) column of report number 068 AB1070-031: "Combined Shortage and Prefill Report, Part Sequence", as shown in Enclosure 1e. This projected usage quantity is automatically subtracted from the on hand quantity shown in the "PRJCT STRS" (Projected Stores) column and the difference is shown in the "RSULT STRES" (Resulting Stores) column. When the inventory manager provides arbitrary M-days, usually selected at four month intervals, these dates appear in the "ISS DAY" (Issue Day) column.

c. Lead Time Computations

Recurring complaints have been made by the Division material planners, addressing the lack of adequate lead time computations in the service support system. The creator of the current system has responded by attempting to compute lead times from the various existing reports, and include them in his issue order computations. Most assemblies have three separate lead times which could be used. Two are listed against the assembly number in the KMS data base. One is listed under Division 60 (manufacturing) and another under Division 68 (service). The difference is due

to decoupling time. The third lead time has been provided to the service inventory manager in the form of a deck of cards, by the materials planning section. They include a compilation of lead times for each of the subassemblies. In one case observed at random by the author, the "60" lead time was fifteen days. The "68" lead time was twenty five days, and the card showed one hundred and ten days. In an effort to be more accurate, the inventory manager called up a part number "explosion" on his KMS terminal, and was computing an even larger lead time by summing those of the component parts. His efforts and perseverance are laudable, but such a process can not possibly be completed for the thousands of parts currently in the planning cycle.

d. Inefficient Utilization of the KMS Inventory Control System

All of these adaptations of KMS reports lead to the inefficient use of the MCS and MRP processes. The bill of material format was designed to facilitate MRP for manufacturing purposes. It has the capability to consider hierachical relationships and demand dependence between parts and assemblies. Utilizing this format to create regional inventory listings wastes computer time. Furthermore, these bills had to be arbitrarily broken down into segments of 250 items in order to facilitate the arduous manual operations required. This was necessary because the size of the regional inventories far exceeds the file size designated for an assembly breakdown. Furthermore, the statistical forecasting features and MRP calculations are not being utilized.

6. Evaluation Summary

The current system requires far too much manual input and variation of the mechanized reports. It is so complex and non standard that the managers are fearful of

loosing the creator of the system, for even a short period of time. No one else understands the modified reports well enough to make them work.

In addition to wasting manhours and computer time, the current system builds an inventory based on an inadequate data base, which is rapidly becoming obsolete. Furthermore, even if the usage report could be modified to provide current annual figures, the method of determining the allocations quantities from the usage data is erroneous. Rather than maintaining an average of four months usage in inventory, the current system merely presumes to compute the projected deficit for the end of an arbitrary period and allocate material to that location before it stocks out. The resulting stock levels could be anywhere between a full years supply and a long term stockout. This depends on the lead time, the periodicity selected for shipment, and the order quantity. There is no systematic method for balancing unit cost, demand frequency, stock out costs, desired inventory effectiveness, economic lot size or lead time.

At the end of the first four month period under the existing system, only 50.7 percent of the computed stock requirements were actually shipped. Reasons cited for this failure are lack of manpower to process the shipments and long lead times required for procurement or manufacture of many of the items. The diligence and experience of the inventory manager may eventually overcome these problems. However, the current system is not providing the type of management information required. The KMS MCS and MRP systems were allegedly designed to provide the required information. Why are they not utilized?

C. KMS MATERIAL REQUIREMENTS PLANNING CAPABILITIES

The KMS MRP module, which has apparently been highly successful in supporting the Division's manufacturing operation, is designed to perform all of the necessary computations and display the desired information in output HGG: "Material Planning Action Report". The system computes projected demand and sets back the time frame based on lead time and decoupling time, and allows for a safety factor if desired. It utilizes the standard Economic Order Quantity (EOQ) formula, based on the unit price, annual use, order cost and holding cost. These factors are further modified by stabilizing factors which are built on the assumption that variations will follow a Poisson Distribution. Suffice it to say that the MRP module contains a sophisticated series of computations which should yield valuable inventory planning information.

The annual usage figure is a sum of the scheduled requirements, special memo requirements, safety stock, and a statistical forecast of unscheduled requirements. It is the Statististical Forecast which has caused the report to be disregarded by the material managers in the service support section. The Statistical Forecast is calculated only from Transaction Code 73 "Issue Parts from Stores to Record Statistical Usage". For whatever reasons, improper coding of service support issues, anomalies in the regional stock issue procedures or some unknown glich in the computations, the resulting figures have been considered unacceptable by the material managers.

1. Required Adaptations

In order to utilize the MCS and MRP modules to replace the cumbersome system of jury rigged "bills of material" now being used, realistic demand forecast data must be provided. There are three possible methods of

providing the data. First, the Statistical Forecast could be used directly as it is calculated in the part history file. This data had been rejected earlier as being inaccurate, but the reason is still unclear. The second possibility is to vary the weighting and or exponential smoothing processes or correct statistical reporting procedures so that the Satistical Forecast becomes usably accurate. If it is determined that the statistical calculations can not be made acceptable, then KMS allows for the Statistical Forecast to be set at any arbitrary value. An average daily usage factor could be obtained by modifying the existing COBOL program which is used to create the "Regional Usage Report" shown in Enclosure 1d. This can be achieved by accessing the KMS part history data base for any desired period, vice the current fiscal year data now being obtained from the Company's IRS files. This value could be weighted for the most recent period and subjected to a stabilizing factor similar to the KMS MCS Statistical Forecast formulae. Manual screening for periodic variations, skewing or comparison with the KMS MCS Statistical Forecast would be possible prior to feeding the factor into the MRP process.

Once an acceptable forecast is provided to the Part History File, the existing MRP and MCS programs should preclude the need for the current laborious system. Furthermore, the material planners will have the same visibility of projected service support requirements that they now have for manufacturing requirements. This will allow the material and inventory managers to concentrate on refining the established guidelines and responding to exceptional requirements.

2. Adjusting Stocking Levels

The safety stock multiplier has been set in the Material Control System at 1.65 for parts with a unit cost greater than one dollar, and 2.33 for those less than one dollar. These multipliers are applied against the square root of the product of the average daily statistical usage, lead time in M-days and the average units on one "statistical" requisition. The result should yield a stock out level of five percent for most items and two percent for those costing less than one dollar, similar to the type of breakdown recommended in the initial study. If the resulting inventory levels are not satisfactory, these values may also be arbitrarily set.

To preclude excess inventory at one regional stockpoint from screening shortages at another, the HGG Unit 00 (Material Planning Action Report) could be requested for each region independently. Safety Factors could be applied to each region separately, or an agregate report could be requested for the Division, with the safety stock allocated only to the home office.

The bottom line is that a few adaptations of the existing MRP and MCS programs should preclude the need for the current laborious systems. The proposed changes will allow the material managers to concentrate on refining the established guidelines and responding to exceptional requirements. I would like to continue pursuant to this end.

Enclosure 1. Examples of "Adapted" Data Products

a) Bill of Material for Stockroom 31

"BILL OF MATERIAL"

```
    818  03/03/82       XPSL - SINGLE LEVEL EXPLOSION                   PAGE 01
PART: A31STOCK01   UNIT: 31   DESC: CHICAGO ALLOC 4MO'S     EM:     DRAW REV:
      PART NUM/  DESCRIPTION/              E                                LCD
K UC  START EFF     STOP EFF    UI QTY/ASY M DR  WC SHRK TSDO UNIT COST  ECO   MDY
0 31 0080820201 SEAL FRAME     EA  32.000 0     000  .00 1120     3.321 MD703 724
0 31 0080822701 SEAL RING      EA   2.000 0     000  .00 0000     2.203 MD703 724
0 31 0080822703 SEAL           EA  30.000 0     000  .00 0100     2.975 MD703 724
0 31 0082058701 CAP 0156 UF 3 EA   1.000 0     000  .00 0000   223.880 MD703 724
0 31 0082078702 HV PLATE XFME EA   1.000 0     000  .00 0600   849.120 MD703 724
0 31 0082080701 CARRIER JAW R EA   1.000 0     000  .00 0000    11.839 MD703 724
0 31 0082080901 INTEGRATOR, P EA   1.000 0     000  .00 4830    40.181 MD703 724
0 31 0082081301 SHAFT JAW ROT EA   2.000 0     000  .00 0000     1.054 MD703 724
0 31 0082081302 SHAFT          EA   1.000 0     000  .00 0000     1.585 MD703 724
0 31 0082081303 SHAFT JAW ROT EA   1.000 0     000  .00 0000     1.201 MD703 724
0 31 0082081501 TIMER PULSE G EA   1.000 0     000  .00 4830    51.842 MD703 724
0 31 0082081506 PCB TIMER  DO EA   1.000 0     000  .00 0000    45.508 MD703 724
0 31 0082086101 CHOKE 1.5HY 2 EA   1.000 0     000  .00 1630   227.695 MD703 724
0 31 0082090502 MOTOR ASY LWR EA   1.000 0     000  .00 0000   253.439 MD703 724
0 31 0082090801 RETICLE OPTIC EA   1.000 0     000  .00 0100    51.218 MD703 724

ENTER NEW PART, CONTINUE CURRENT PART, PA-1 FOR MENU
SCR XPSL    P/N A31STOCK01    UNT 31    ORD              VEN          OPT P
```

b) Part Usage by Region: Report from IRS File

OUS A09XAN-001 REGION - MIDWEST RESPONSIBILITIES - 6730,6731,6732 PART USAGE BY REGION DATE AUG. 1, 1981 PAGE 1

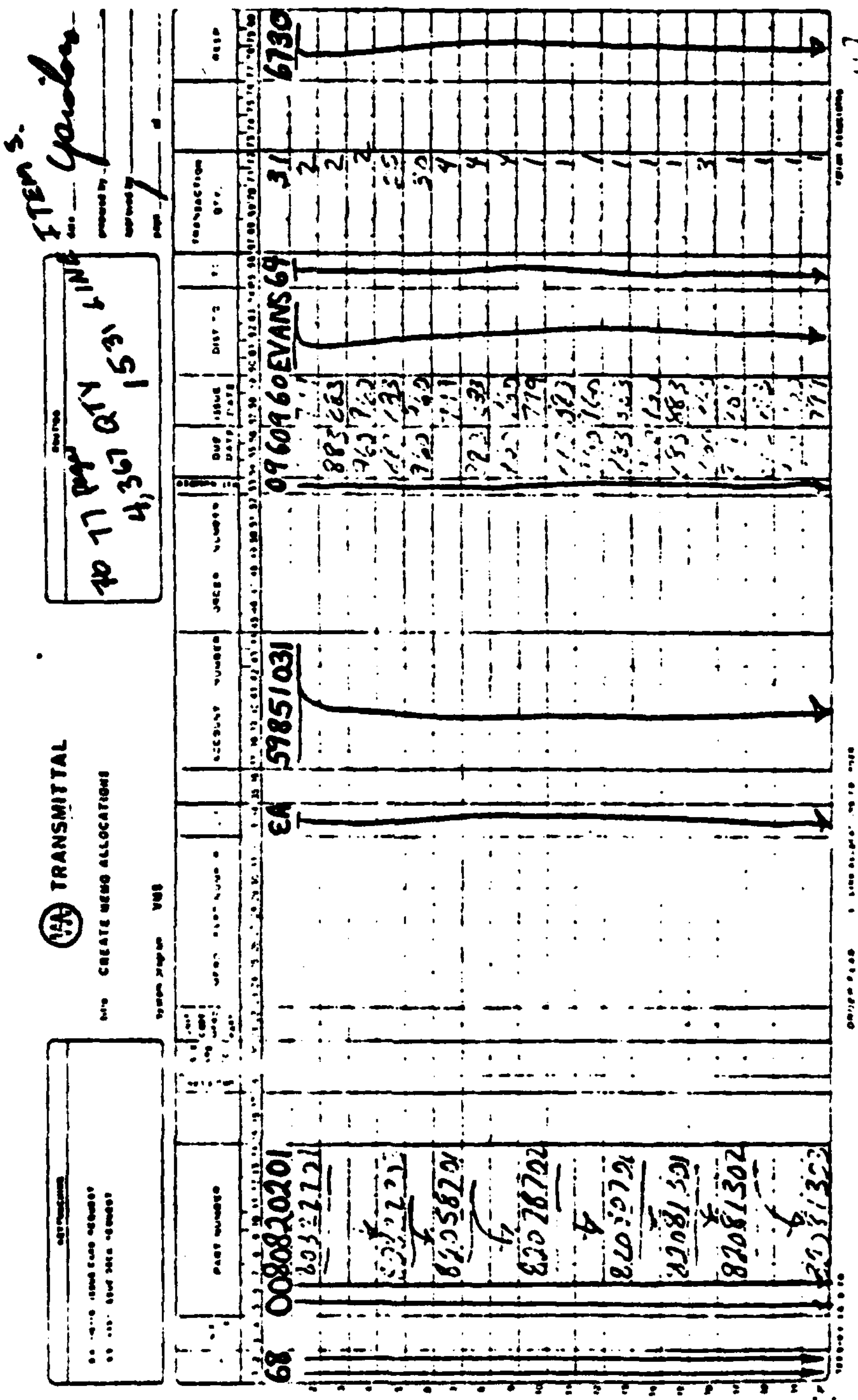
PART NO	DESCRIPTION	OCT (1ST QTR)	NOV	DEC	JAN (2ND QTR)	FEB	MAR	APR (3RD QTR)	MAY	JUN	JUL (4TH QTR)	AUG	SEP	USAGE TO DATE	AV MON USAGE	UNIT COST	$ USAGE TO DATE	ON HAND QUANTITY	PROD LINE
0046441001	TUBE SHIEL	1												1	.1	2639.25	2639.25		12
0000020201	SEAL FRAME		6	12			26	8	6	22				76	7.6	2.92	227.36		01
0000022703	SEAL		6	12			18	8	6	22	8			78	7.8	2.63	205.40		01
0002050701	CAP .01560										1			1	.1	170.63	170.63		01
0002070702	XFMR HIGH		1		1									2	.2	746.59	1493.18		01
0002080901	INTEGRATOR	2			1	1	1							5	.5	40.18	200.90		01
0002081301	SHAFT JAM						2							2	.2	0.99	1.98		01
0002081302	SHAFT JAM							2						2	.2	1.51	3.02		01
0002081303	SHAFT JAM							2						2	.2	1.20	2.40		03
0002081501	TIMER & DE							1						1	.1	46.54	46.54		01
0002081506	PCB TIMER								1					1	.1	92.03	92.03		01
0002086101	CHOKE 1.5H	2			1	1	1							5	.5	219.22	1096.10		01
0002090502	MOTOR ASSY							1		1				2	.2	229.33	458.66		01
0002090801	RETICLE OP	2	1		2	4	1	1	1	4	1			17	1.7	51.21	870.70		01
0002094302	JAM POS IN	1												1	.1	199.20	199.20		01
0002094303	INDICATOR			1										1	.1	160.30	160.30		01
0002101702	MIRROR FIX								1					1	.1	10.00	10.00		02
0002103071	R H DRIVE					2								2	.2	145.27	290.54		01
0002103075	BALL,BUSHI						2							2	.2	23.54	47.08		01
0002103076	RH DRIVE A					2			1					3	.3	99.47	298.41		01
0002103077	LH DRIVE A					5			4					9	.9	93.87	844.83		01
0002103078	KIT JAM AS				2		2							4	.4	108.45	433.80		01
0002103079	KIT JAM AS				2		2							4	.4	105.08	420.32		01
0002155304	RH CL FIN						1				1			2	.2	6203.74	12407.48		01
0002155372	GUIDE PACK							1						1	.1	10.71	10.71		01
0002195304	RH CL FIN	1												1	.1	3047.77	3047.77		01

c) Combined Shortage and Prefill Report: Unit 31

068 AB1070-031 UNIT 31 RADIATION SERVICE — COMBINED SHORTAGE & PREFILL REPORT (PART SEQUENCE) — FEB 21, 1982 — MDAY 806 — PAGE 1

PART NUMBER	DESCRIPTION	TID	PRJCT STRS	CUMSH /ALLO	RSULT STRS	INSP /DMR	QTYDUE STORE	DAY DUE	ST BC	ORDER/ VEND NR	ISS DAY	DISTR	ASSEMBLY OR SALES ORDER	ORDER OR ACCNT NR	-	DOC NR	ORDER QTY	BO
00-808202-01	SEAL FRAME	112	65	32A	33						801	EVANS	A3-1STOCK-01	59851031	0	525066	1	
			33	32A	1						883	EVANS	A3-1STOCK-01	99999031	0	524836	1	
			1	32A	31-						960	EVANS	A3-1STOCK-01	99999031	0	524606	1	
PLACE ORDER																		
00-808227-11	SEAL RING	N 000	0	2A	2-						801	EVANS	A3-1STOCK-01	59851031	0	525067	1	
			2-	2A	4-						883	EVANS	A3-1STOCK-01	99999031	0	524837	1	
			4-	2A	6-						960	EVANS	A3-1STOCK-01	99999031	0	524607	1	
PLACE ORDER																		
00-808227-03	SEAL	010	12	30A	18-						801	EVANS	A3-1STOCK-01	59851031	0	525068	1	
			18-	30A	48-						883	EVANS	A3-1STOCK-01	99999031	0	524838	1	
			48-	30A	78-						960	EVANS	A3-1STOCK-01	99999031	0	524608	1	
PLACE ORDER																		
?0-820787-02	HV PLATE XFMER	060	0	1A	1-						801	EVANS	A3-1STOCK-01	59851031	0	525C70	1	
			1-	1A	2-						883	EVANS	A3-1STOCK-01	99999031	0	524840	1	
			2-	1A	3-						960	EVANS	A3-1STOCK-01	99999031	0	524610	1	
PLACE ORDER																		
00-820807-01	CARRIER JAW ROT	000	1	1A	0						801	EVANS	A3-1STOCK-01	59851031	0	525071	1	
			0	1A	1-						883	EVANS	A3-1STOCK-01	99999031	C	524841	1	
			1-	1A	2-						960	EVANS	A3-1STOCK-01	99999031	0	524611	1	
PLACE ORDER																		
00-820813-01	SHAFT JAW ROTAT	000	3	2A	1						801	EVANS	A3-1STOCK-01	59851031	0	525073	1	
			1	2A	1-						883	EVANS	A3-1STOCK-01	99999031	0	524843	1	
			1-	2A	3-						960	EVANS	A3-1STOCK-01	99999031	0	524613	1	
PLACE ORDER																		
00-820813-03	SHAFT JAW ROTAT	000	0	1A	1-						801	EVANS	A3-1STOCK-01	59851031	0	525075	1	
			1-	1A	2-						883	EVANS	A3-1STOCK-01	99999031	0	524845	1	
			2-	1A	3-						960	EVANS	A3-1STOCK-01	99999031	0	524615	1	
PLACE ORDER																		
00-820861-01	CHOKE 1.5HV 25K 183		2	1A	1						801	EVANS	A3-1STOCK-01	59851031	0	525078	1	
			1	1A	0						883	EVANS	A3-1STOCK-01	99999031	0	524848	1	
			0	1A	1-						960	EVANS	A3-1STOCK-01	99999031	0	524618	1	
PLACE ORDER																		
00-820905-02	MOTOR ASY LWR J	000	1	1A	0						801	EVANS	A3-1STOCK-01	59851031	0	525079	1	
			0	1A	1-						883	EVANS	A3-1STOCK-01	99999031	0	524849	1	
			1-	1A	2-						960	EVANS	A3-1STOCK-01	99999031	0	524619	1	
PLACE ORDER																		
00-820943-03	INDICATOR ASSY	000	1	1A	0						801	EVANS	A3-1STOCK-01	59851031	0	525081	1	
			0	1A	1-						883	EVANS	A3-1STOCK-01	99999031	0	524851	1	
			1-	1A	2-						960	EVANS	A3-1STOCK-01	99999031	0	524621	1	
PLACE ORDER																		

d) KMS Allocation Transmittal



e) Combined Shortage and Prefill Report: Unit 00

```
050 AB1070-035  UNIT     RADIATION SERVICE        COMBINED SHORTAGE & PREFILL REPORT     FEB 12, 1982   MDAY 036        PAGE   1
                                                          (PART SEQUENCE)

0-------------------PART DATA-----------------------0------REPLENISHMENT DATA-----0------------------ASSEMBLY  DATA-----------------0
                                PROJCT CUMSA RSULT PINSP OTYDUE   DAY ST ORDER/  DISS         ASSEMBLY OR  ORDER OR              ORDER DDP
PART NUMBER    DESCRIPTION  TSD  STRS /ALLD STRES 0 /RED STORE   DUE SC VEND NR MDAY DESTR SALES ORDER  ACCNT NR C DOC NR  QTY

00-500227-31 SEAL RING      000    0    2A    2-0                              0799 EVANS               59551031 3 033350    2  3
                                   2-   2A    4-0                              0883 EVANS               59551031 3 033349    2  3
                                   4-   2A    6-0                              0960 EVANS               59551031 3 033351    2  3
                                                0                              0
PLACE ORDER
03-530227-33 SEAL RING      353    35   7A    78 0                             0753 PACHA               59551342 3 613331    7 65
                                   78   38A   40 0                             0821 PACHA               59551042 3 613033   30 65
                                   40   23A   15 0                             0883 EVANS               59551031 3 031283   25  3
                                   15   39A   23-0                             0901 PACHA               59551042 3 613032   30 65
                                   23-  39A   53-0                             0960 EVANS               59551031 0 031282   30  3
                                                0                              0
PLACE ORDER
00-509268-01 GASKET         000    7    385   31-0   0   293   380 5N 59800890 0459                     91199396 3 593329   50 307
                                   31-  64    37-0                             0663 PALTD ON-THUSEA-GE  59531379   713082    6 135

03-516764-30 CORONA SHIELD  000    4    2A    2 0                              0753 PACHA               59551342 0 613020    2 65
                                   2    2A    0 0                              0821 PACHA               59551042 3 613019    2 65
                                   3    2A    2-0    0    13   619 0J 59801602 0901 PACHA               59551342 3 613018    2 65
                                                0                              0
SLIP    ORDER  1 -  62 DAYS
03-523507-01 CAP .0150UF 30K 163   7    1A    6 0                              0663 PALTD ON-THUSEA-GE  59531370   713009    1 135
                                   4    4A    2 0                              0799 EVANS               59551031 0 033341    4  3
                                   2    4A    2-0    0     2   813 3M 59801603 0883 EVANS               59551331 3 033343    4  3
                                   2-   4A    6-0    0     2   821 3M 59801603 0960 EVANS               59551331 3 333342    4  3
                                                0    0     2   860 39 59801603 0
                                                0                              0
SLIP    ORDER  1 -  73 DAYS
03-520787-32 XFMR HIGH VOLTA 163   1    1A    0 0                              0799 EVANS               59551331 0 033313    1  3
                                   0    1A    1-0    0     1   781 5N 59850060 0883 EVANS               59551031 3 033312    1  3
                                   1-   1A    2-0    0     1   786 5N 59850060 0960 EVANS               59551331 3 333316    1  3
                                                0                              0
SLIP    ORDER  1 - 102 DAYS
00-520807-01 CARRIER JAW ROT 000   0    1A    1-0    0     3   763 0J 59801270 0883 EVANS               59551031 3 031212    1  3
                                   1-   1A    2-0                              0960 EVANS               59551031 3 031211    1  3
                                                0                              0
SLIP    ORDER  1 - 190 DAYS
00-520813-01 SHAFT  JAW ROTA 000   0    4A    4-0                              0663 PALTD ON-THUSEA-GE  59531379   713072    4 135
                                   4-   1A    5-0                              0883 EVANS               59551331 3 333364    1  3
                                   5-   3A    8-0                              0963 EVANS               59551331 3 333365    3  3
                                                0                              0
PLACE ORDER
03-520813-32 SHAFT JAW ROTAT 000   3    5A    5-0                              0663 PALTD ON-THUSEA-GE  59531379   713307    5 135
                                   5-   2A    7-0                              0750 PACHA               59551042 0 613302    2 65
                                   7-   1A    8-0                              0801 EVANS               59551331 3 333319    1  3
                                   8-   2A    10-0                             0821 PACHA               59551342 3 613305    2 65
                                   10-  1A    11-0                             0853 EVANS               59551331 3 033318    1  3
                                   11-  2A    13-0                             0901 PACHA               59551342 3 613331    2 65
                                   13-  1A    14-0                             0960 EVANS               59551331 3 033317    1  3
                                                0                              0
PLACE ORDER
```

APPENDIX C

MEMORANDUM OF 20 APRIL 1982

From: Gary W. Strawn

To: Mr. Ed Kelly

Via: Mr. Jim Younkin

Subj: Implementation of MRP for Medical Group Service Support

A. EVALUATION OF STATISTICAL FORECASTS AS PREDICTORS

A sample of 100 part numbers was selected from the 2800 which showed usage in the reports dated August 1981 (the time frame being used in the current system). Statistial Forecasts in the Part History File and the average usage from the Regional Usage Report (IRS File) were compared with the recorded usage for the six month period: October, 1981 through March, 1982.

An empirical comparison of the raw usage data recorded for each part on a month by month basis, revealed the two predictors to be so far apart that it seemed there must be a problem in the data inputs. There were three apparent problems which explain some of the disparity. First, although the two reports were dated "August 31", the Part History File included August data, whereas the Regional Usage Report did not. Secondly, the Regional Usage Report only included data for the current fiscal year, in this case, ten months. While the Part History File only displayed data from the past six months, it calculated the Statistical Forecast over an unlimited period, based on the weighting formulas

described in the KMS manual. The third problem came from cancelled orders, the cancelled data was not removed from the IRS file in time to keep it from appearing in the report. The cancelled orders had been properly removed from the Part History Report. A total of nine part numbers in the sample were affected by these administrative problems. The remaining ninety two items showed absolute correlation in the raw usage data, which supports the Service Manager's claim that the data is being input correctly.

Regression analysis performed on the IBM 3033 computer at the Naval Postgraduate School, utilizing the IDA software package, revealed that the IRS data was not statistically significant as a predictor of the actual usage recorded. The part history value was statistcally significant at the ninety five percent confidence level, but the skewing of the residual values was great enough to cast serious doubt on its practical usefulness.

The most obvious example of an erronious predictor shown in the sample data (Enclosure 1) is part number 0083472602. The Part History File showed a demand record of twelve in April, ten in May and 110 in August. Its computed Statistical Forecast (converted to a Monthly figure for comparison purposes) was 40.4. The actual usage for the six month test period was zero. The Regional Usage Report did not have the August data, but the remaining data was identical. The average monthly usage was computed to be 6.8. If the August data was included the average would have been twelve. The straight average in the Regional Usage Report was obviously the best predictor in this instance, even though it was computed from the significantly smaller IRS data base. These results lead to the hypothesis that a flattened response curve could reduce the erronious skewing of the weighted Statistical Forecast in the Part History File.

1. __The Exponential Smoothing Factor__

The over responsiveness to sporadic changes in usage is a funtion of the Exponential Smoothing Factor (ESF). It is designed to increse responsiveness to changing market trends This responsiveness is neither necessary or desirable when responding to the relatively slow changes expected in dealing with mechanical or electronic failure rates, as approximated by either of the commonly used Exponential or Weibull distributions. A review of the sample data with inventory and service personnel, reveals that most sporadic increases in usage appear to be a result of some special set of circumstances or errors in ordering. In either case, it is not desirable to allow these instances to overly influence future stocking levels.

The skewing can be reduced by reducing the ESF value used in the computations. A discussion with personnel in the Management Information Section has resulted in reducing the ESF to ".154" which approximates a twelve month moving average. The selection was an arbitrary one, to be used on a trial basis only.

This smoothed Statistical Forecast is still only a crude predictor of future requirements. However, it is more accurate than the values being used now, and is approaching optimal usage of the historical data available. It should provide a fairly stable input to the MRP process without any program changes. Continued monitoring of both input and output data should continue, and further adjustment of the ESF will probably be required.

2. __Coordination with Manufacturing Division__

The implementation planning meetings to date, have concentrated on procedures for handling the service support inventory requirements within the Material Planing Section

of the Manufacturing Division (60). Excellent progress has been made, and an agreement to utilize the modified Statistical Forecast as an input to the MRP process has been reached. Concern has been expressed over the validity of the lead time computations, if the statistical input is made directly to Division 60 MRP. An alternative would be to run a separate MRP for Division 68 with specifically designated lead times. Presumably, the results of this process would be treated as required orders which are submitted directly to purchasing, or placed into the Division 60 MRP as planned requirements.

The internal processes of material procurement are beyond the scope of this study. However, there are two salient points to be made. First, the Statistical Forecast is only an educated guess at future demand. With the nominal correlation shown in this evaluation, it would be best if the resulting demand could be stated in terms like "a few of these" and "a bunch of those". The predictive value is really no more accurate just because a computer assigns it a numerical value. The problem becomes serious when material planners, who are used to being held accountable on a quantitative basis, lend more value to the numbers than they deserve. We can then waste a great deal of effort and expense trying to meet these "required delivery schedules" when they are only predictions of routine demand.

Secondly, concern for lead time in this instance is greatly unwarranted. Because, the statistical demand is based on historical data, the initial demand will always appear to be late by the amount of lead time prescribed. For example, if the Statistical Forecast for an item is one every two months and the lead time is 100 days, the first month the input to MRP, will produce an overdue demand for two, plus the safety factor. The system will continue to

order one every two months as long as the usage stays the same. If usage drops off, we are left with excess in inventory plus the two already in the ordering process. There is a fallacy in considering statistical forecasts in the same way we do demand: the requirements are much more likely to disapear or multiply before the material arrives. The lead time value helps by speeding the response to any increased demand but it equally slows the responsiveness to decreasing trends.

Efforts to improve lead times should be limited by the level of accuracy of the Statistical Forecasts. Attempts to gain an edge on this unpredictable demand by adding to lead times will only add expense. All we can hope to do is gain a hedge against the routine demands, and conserve manpower for response to the exceptions.

3. Periodic Review

One very valid concern expressed by the material planning division is that the Statistical Forecast will be allowed to run the system unchecked. Again, it must be emphasized that the predictive value of the Statistical Forecast, even with increased smoothing, will be questionable. Periodic review and modification by experienced material planners, focussing on exceptional circumstances and known idiosyncrassies, is imperative for success. A data base access program, which would allow easy access to the Part History File, would make such a periodic review possible. Hopefully, it will also flag significant aberrations in the data, for management review.

Adjustment of stocking levels for specific equipments, can be accomplished in two ways. The MRP's EOQ computations, if left intact, will vary stocking levels in accordance with the relative cost and demand of each item. Desired manipulation of stocking levels to accommodate

subjective evaluations of the importance of an item or to compensate for the fact that it is out of production, should be made by varying the Safety Factor.

B. ADVANTAGES

The greatest advantage of the system is in manpower savings. By utilizing the existing MCR and MRP automated systems, most of the work being done by the inventory manager can be eliminated. His efforts can now be concentrated on handling exceptional demands and periodically reviewing the computed Statistical Forecasts for anomalies. The latter task should be aided by the addition of the Statistical Forecast review program now being written. Ideally, it will convert the daily values to more easily understood monthy figures, for display puposes only. The program should convert changed values into daily figures before inserting them into the Part History File.

There should not be a requirment to use the Regional Usage Report average, but it should be retained for comparison purposes, at least until an optimal ESF has been determined.

Enclosure 1. A Comparative Sample of Usage Predictors

The following is a sample of 100 part numbers selected from the KMS Division 68 Part History file "PARTHIST" and the Regional Usage Report "IRSUSAGE" dated August 1981. The computed usage data, converted to monthly figures, are compared with the recorded average usage for the six month period: October, 1981 through March, 1982 "ACTUSAGE".

PARTNUM	PARTHIST	IRSUSAGE	ACTUSAGE
0000003900	01.2	00.5	00.0
0000047400	00.3	00.1	00.0
0000062300	00.5	00.2	00.0
0004741100	01.0	00.4	00.0
0024556201	00.3	00.1	00.0
0080188001	01.2	00.5	00.0
0080193501	00.5	00.2	00.0
0080196001	00.5	00.2	00.0
0080413405	02.5	01.0	00.0
0080413406	02.5	01.0	00.0
0080413407	02.5	01.0	00.0
0080413408	02.5	01.0	00.0
0080413409	02.5	01.0	00.0
0080413410	02.5	01.0	00.0
0080525701	00.5	00.2	00.0
0080525702	00.5	00.2	00.0
0080890601	00.5	00.2	00.0
0080926801	00.3	01.4	00.0
0080970201	00.7	00.3	00.0
0080976701	00.3	00.1	00.0
0081386001	00.3	00.1	00.0
0081476501	00.0	00.3	00.0
0082094303	00.4	00.1	00.3
0082095102	00.0	00.2	00.0
0082096201	00.2	00.2	00.0
0082096901	00.0	00.0	00.0
0082196601	00.0	00.0	00.0
0082196701	00.4	00.2	00.0
0082196902	00.0	01.3	00.3
0082197002	00.4	01.3	00.1
0082504604	00.5	00.9	00.1
0082504608	00.2	00.1	00.0
0082505805	00.4	00.1	00.0
0082505807	00.4	00.2	00.0
0082615412	00.0	00.1	00.0
0082636202	00.0	00.6	00.0
0082736001	01.9	00.4	00.9
0082736002	00.5	00.4	00.9
0082736003	00.5	00.4	00.9
0082737203	01.2	00.2	00.0
0082851701	00.3	00.0	00.1
0082851702	01.9	03.3	00.7
0082851801	01.6	02.4	01.0
0082853201	07.0	04.1	01.9
0082853503	00.0	00.3	00.0
0082901581	04.0	00.1	00.7
0082925012	00.0	00.1	00.1

PARTNUM	PARTHIST	IRSUSAGE	ACTUSAGE
0082925015	00.0	00.2	00.3
0082974702	00.4	00.0	00.0
0083013001	00.2	02.8	00.9
0083019901	02.1	06.9	02.0
0083228374	00.8	00.2	01.0
0083230701	00.0	00.5	00.0
0083230801	00.4	00.0	00.0
0083268001	00.4	00.0	00.0
0083472602	40.4	06.8	00.0
0083569502	02.9	04.2	03.3
0083761303	01.7	00.8	00.3
0083761382	00.4	00.3	00.0
1231396012	00.5	00.2	00.0
1231396024	00.2	00.2	00.0
1231396040	00.0	01.4	03.0
1231397264	00.0	00.5	04.3
2080004100	00.0	00.1	00.4
2083971100	05.3	03.2	01.9
2083974000	00.0	00.1	00.0
2083981300	00.1	00.6	00.4
2083981400	00.8	00.0	00.0
2212999400	00.5	00.8	00.0
2231980300	00.5	00.5	00.3
2242996800	00.2	00.0	03.4
2759190800	00.7	01.5	02.7
2759190900	00.0	01.0	02.4
2759191100	00.0	00.6	01.0
2759191300	00.3	00.2	00.3
2899595900	00.0	00.2	00.0
2899989400	00.4	00.0	00.0
2899994100	00.0	00.4	00.0
2915000000	00.4	00.5	00.1
3230144700	00.4	00.2	00.0
3849998000	00.0	00.1	00.0
3899999100	06.9	07.5	04.1
4414799000	00.0	00.3	00.1
5619981200	00.0	00.1	00.0
6260006800	00.7	00.0	00.0
6260006801	00.1	00.6	00.6
6260008801	00.0	00.0	00.0
6260044300	00.0	00.4	00.0
6260128601	00.0	00.3	00.1
6292000101	00.6	00.3	00.0
6689998100	00.0	00.4	00.0
7120001800	00.9	00.5	00.0
7121982800	00.0	00.2	00.0
7163984000	01.0	00.0	00.0
7163984100	00.3	00.1	00.0
7163986400	00.1	00.3	00.0
7344003000	00.0	00.3	00.0
7344061000	00.0	00.8	00.4
7859014200	00.2	00.2	00.0
7859991700	00.0	01.4	00.4

APPENDIX D

REGRESSION ANALYSIS OF USAGE PREDICTORS

The following regression products were computed using the IDA software package on the IBM 3033 computer at the Naval Postgraduate School, Monterey, California.

The first series of reports show regression of Actual Usage data (dependent variable) against Part History data (independent variable). The second series show regression of Actual Usage data (dependent variable) against average Regional Usage from the IRS file (independent variable).

A. PART HISTORY AS A PREDICTOR OF ACTUAL USAGE

```
COMMAND> **** PROB ****
DISTRIBUTION * STUD * OPTION * I *
DEGREES OF FREEDOM = 98
          PR(L<T<U) =  0.0202
                  L =  2.0780    U =  9999.0
          PR(L<T<U) <  0.0001
                  L =  11.071    U =  9999.0
```

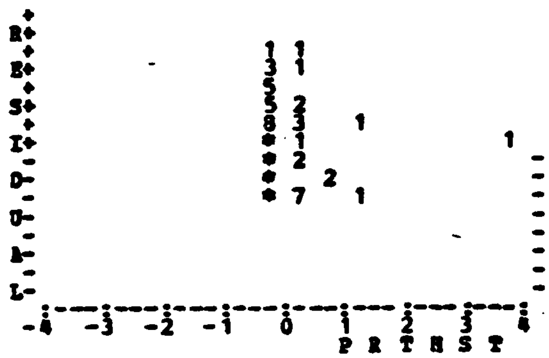
The first probability value "0.0202" being less than 0.05 allows us to make the following statement:

> At the 95% confidence level we may reject the hypothesis that the slope of the regression line is zero.

That is, we may reject the hypothesis that there is no correlation between Actual Usage and the Part History predictor.

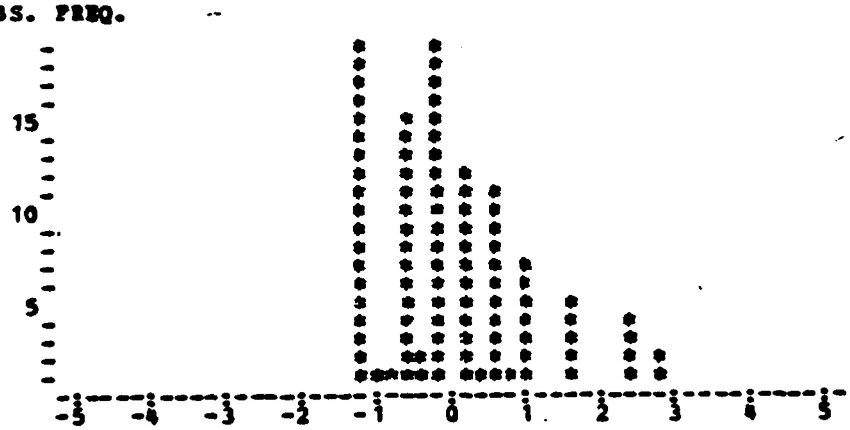
The second probability value refers to a constant.

```
COMMAND> **** COEF ****

VARIABLE  B(STD.V)      B          STD.ERROR(B)    T

PRTHST     0.2054    1.1520E+07    5.5433E+06    2.078
CONSTANT   0         2.5798E+08    2.3302E+07   11.071

COMMAND> **** ANOV ****

  SOURCE        SS          DF       MS            F
REGRESSION  2.24452E+17     1    2.24452E+17    4.32
RESIDUALS   5.09310E+18    98    5.19705E+16
  TOTAL     5.31756E+18    99    5.37127E+16

COMMAND> **** YvsX ****
```



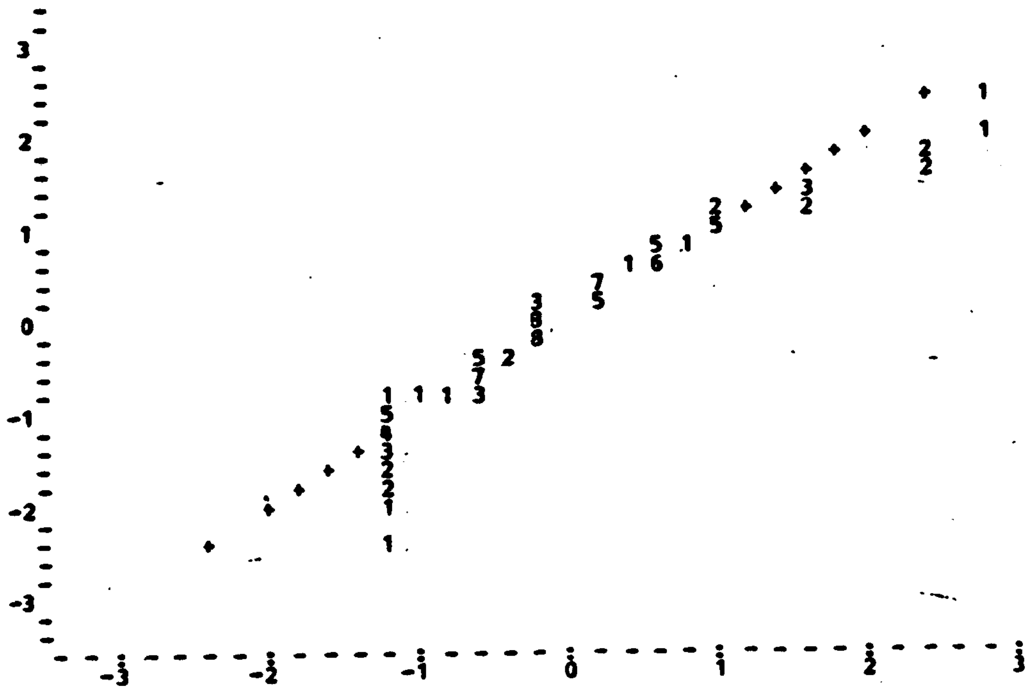
HISTOGRAM

ABS. FREQ.



```
MEAN        =  0.0
STD. DEV.   =  2.2797E+08
SAMPLE SIZE =  100
```

```
COMMAND> **** SUMM ****

              MULTIPLE R  R-SQUARE
UNADJUSTED      0.2054     0.0422
 ADJUSTED       0.1801     0.0324

STD. DEV. OF RESIDUALS = 2.2797E+08
N =  100
NORMAL CUMULATIVE PROBABILITY PLOT OF RESIDUALS
```



```
                         FREQUENCY DISTRIBUTION
                         * 1 1 F 2 *  C 1 B 1 7     5      8  2
    -3        -2        -1        0        1        2        3

NOTE:  FREQUENCIES OVER 15 INDICATED BY '*'
       A=10, B=11, C=12, D=13, E=14, F=15

MEAN =  0.0
STD.DEV =  2.2797E+08
SKEWNESS =  8.5940E-01
KURTOSIS =  1.8834E-01
STUDENTIZED RANGE =  4.0489E+00
SAMPLE SIZE = 100
```

B. AVERAGE REGIONAL USAGE AS A PREDICTOR OF ACTUAL USAGE

```
COMMAND> **** PROB ****
DISTRIBUTION * STUD * OPTION * I *
DEGREES OF FREEDOM = 98
          PR(L<T<U) =  0.4217
                  L =  0.1980   U =  9999.0
          PR(L<T<U) <  0.0001
                  L =  7.6620   U =  9999.0
```

The first probability value "0.4217" being greater than 0.05 allows us to make the following statement:

> At the 95% confidence level we may not reject the hypothesis that the slope of the regression line is zero.

That is, we may not reject the hypothesis that there is no correlation between Actual Usage and the Average Regional Usage predictor.

The second probability value refers to a constant.

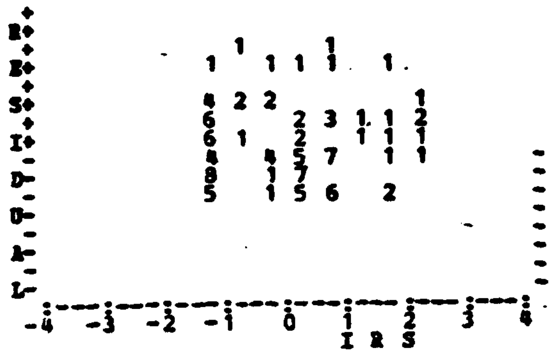
COMMAND> **** COEF ****

VARIABLE	B(STD.V)	B	STD.ERROR(B)	T
IRS	0.0200	1.7103E-02	8.6354E-02	0.198
CONSTANT	0	2.6301E+08	3.4325E+07	7.662

COMMAND> **** ANOV ****

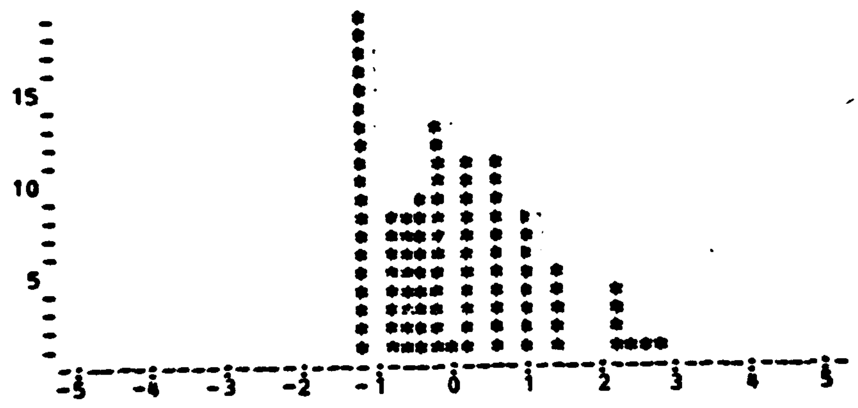
SOURCE	SS	DF	MS	F
REGRESSION	2.12755E+15	1	2.12755E+15	0.04
RESIDUALS	5.31543E+18	98	5.42391E+16	
TOTAL	5.31756E+18	99	5.37127E+16	

COMMAND> **** YvsX ****



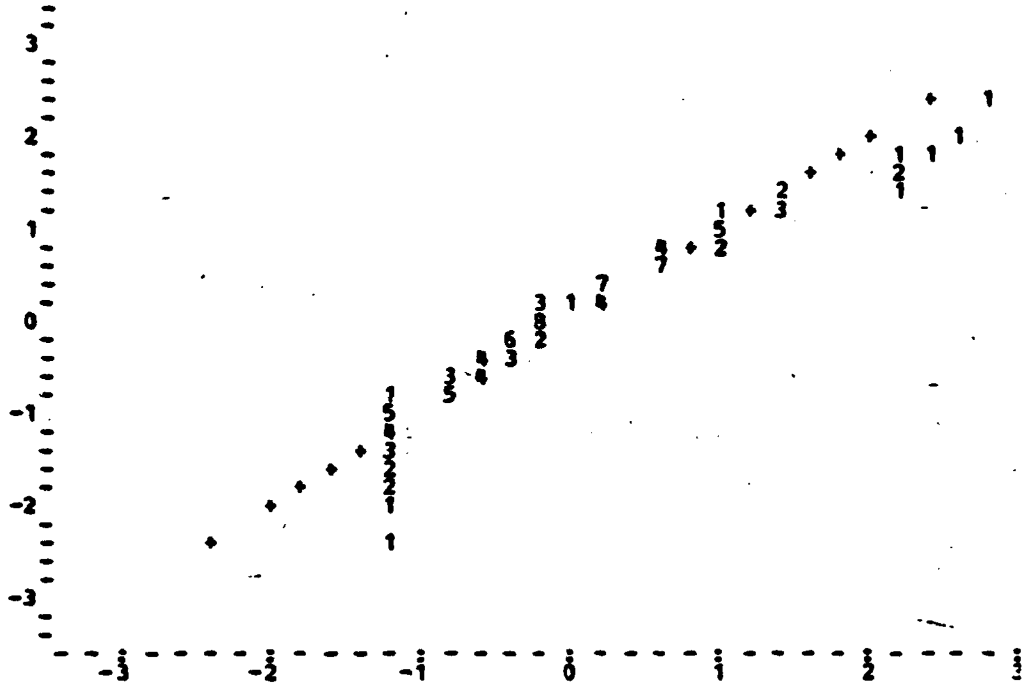
HISTOGRAM

ABS. FREQ.



MEAN = 0.0
STD. DEV. = 2.3289E+08
SAMPLE SIZE = 100

```
COMMAND> **** SUMM ****

              MULTIPLE R   R-SQUARE
 UNADJUSTED     0.0200       0.0004
  ADJUSTED      0.0          0.0

STD. DEV. OF RESIDUALS = 2.3289E+08
N =  100
NORMAL CUMULATIVE PROBABILITY PLOT OF RESIDUALS
```



```
                       FREQUENCY DISTRIBUTION

                        *  8 8 9 D 1 B   B   8   5       4 1 1 1
  - - 3 - - - - - 2 - - - - 1 - - - - 0 - - - - 1 - - - - 2 - - - - 3
     -3          -2        -1         0         1         2         3

NOTE:  FREQUENCIES OVER 15 INDICATED BY '*'
       A=10, B=11, C=12, D=13, E=14, F=15

MEAN =  0.0
STD.DEV =  2.3289E+08
SKEWNESS =  8.8071E-01
KURTOSIS =  1.1412E-01
STUDENTIZED RANGE =  3.9158E+00
SAMPLE SIZE = 100
```

APPENDIX E

KELLY MANUFACTURING SYSTEM STATISTICAL FORECAST CALCULATIONS

STATISTICAL FORECAST CALCULATION - EXAMPLE

EXAMPLE: P/N 00-824826-01

From the Report: L = 4.96 (Last Estimate)
T = .09 (Last 'old' weight factor)
W = .12 (New weight factor)

Calculate Last Actual Demand: D = 3 + (794-774) = .15

Calculate Statistical Demand: N = (.20 x .15) + (1 - .20) 4.96 = 3.998

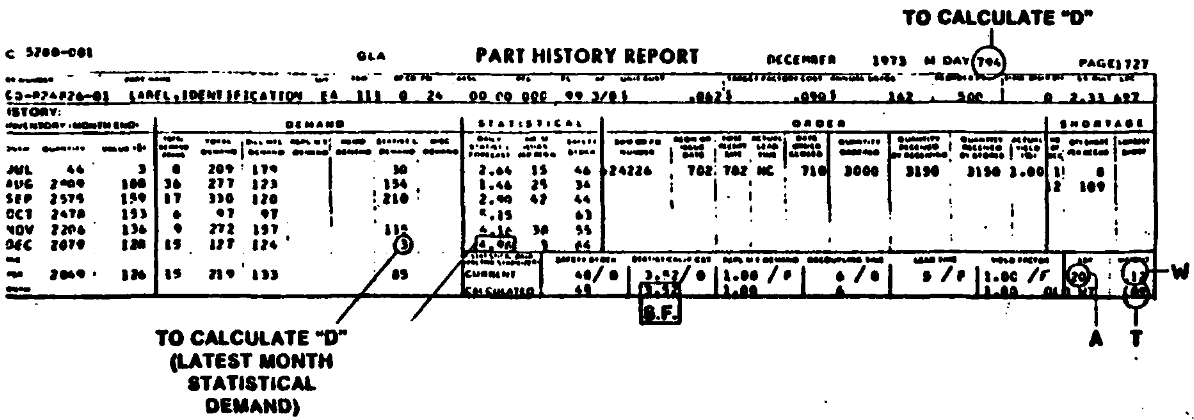
W = .20 (3.998 - 4.96) + (1 - .20) .09 = -.120

$$\boxed{\begin{aligned} N &= (A \times D) + (1 - A)L \\ W &= A(N-L) + (1 - A)T \\ SF &= N + \frac{(1-A)}{A} W \end{aligned}}$$

$$S.F. = 3.998 + \frac{(1 - .20)}{.20} (-.120)$$

S.F. = 3.998 + (-.480)

S.F. = 3.518 or 3.52 per day



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